Development and Implementation of Modifications for Acceleration Data Analysis Package G-DAP – Phase 4

Final Report

Ziren Lu, John Yeow, Alex Kapps

Engineering Services Inc.
1 Bedford Rd, Unit 5
Toronto, Ontario Canada M5R 2J7

Contract Number: W7711-027805

Defence Research and Development Canada - Toronto

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Abstract

This final report summarized the development and implementation of advancements and modifications for G-DAP software package. G-DAP (*The Acceleration /Gz/ Data Analysis Package*) is a Labview-based package for custom-designed analysis of physiological data pertinent to acceleration physiology research conducted at DRDC-TORONTO. G-DAP automates review, playback, signal processing, and analysis of data acquired in human centrifuge, tilt-table or flight experiments. Furthermore, G-DAP automatically calculates predefined and/or custom-defined physiological indices used in acceleration physiology research, such as blood flow analysis and calculation of related indices (e.g., cardiac index), and ear-opacity signals identification and analysis (based on an adaptive peak detection algorithm). In this project, new functions are added that enable more sophisticated and comprehensive analysis, as well as handling new types of advanced acceleration research and experimental protocols performed using both Tilt-Table setup and human centrifuge.

Résumé

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Executive summary

G-DAP (*The Acceleration /Gz/ Data Analysis Package*) is a Labview-based computer package for custom-designed analysis of physiological data pertinent to acceleration physiology research conducted at DRDC-TORONTO. G-DAP supports several different applications, such as: (i) playback data acquired from a human centrifuge, tilt-table or flight experiment; (ii) provide signal processing features for further analysis of specific data; and (iii) automatically calculate predefined and/or custom-defined physiological indices used in acceleration physiology research, such as blood flow analysis and calculation of related indices (e.g., cardiac index), and ear-opacity signals identification and analysis (based on an adaptive peak detection algorithm), etc.

The project has addressed the development and implementation of new features for G-DAP software as needed to support advanced acceleration research currently undertaken by ALS. Also, the project augments G-DAP user interfaces to support the implementation of new capabilities.

The original G-DAP package possessed the following features and capabilities:

(i) Capability of loading binary and ASCII files with predefined formats;

(ii) Display of the loaded data in strip chart format (the maximum number of channels on each display should be set based on the size of the monitor);

(iii) The data strips can be marked (using an appropriate event marker) by the user;

(iv) Capability of exporting the loaded and processed data from a pre-defined format to the spreadsheet format (Excel);

(v) Default selections across all channels in correspondence with a window defined by the user for a single channel;

(vi) Capability of printing the selected waveforms to a postscript printer or screen dump the selected waveforms (plot) into other applications (e.g. MS Word or MS Power Point);

(vii) Availability of SWAP-like features such as Zoom, Front, Back, Redisplay. In general, most of the SWAP commands are built using Labview. The most important part of the SWAP is the SPAN

command that can be used to analyze a block of data. All features of SPAN command are implemented. Moreover, the capability of saving and sorting the selected analyzed data with sorting the collected data based on time stamps is implemented;

(viii) Capability of calculating systolic, diastolic, and RR interval for blood pressure and ECG waveforms (automated blood pressure analysis) for each heartbeat in the file;

(ix) Capability of user-defined Gz window with different timing events (Push-Pull or Pull) for extracting, analyzing, and saving the other channels data to the spreadsheet format;

(x) Capability of editing the calculated Gz reference points interactively;

(xi) Capability of choosing the Gz profile based on the experimental facility used (e.g., in flight, DRDC-TORONTO centrifuge, Veda centrifuge, Tilt-table);

(xii) Implementation of Labview based analysis routines such as FFT, Spectrum, Filtering, and Correlation;

(xiii) Provisions for user-defined channel configuration for maximum of 50 channels;

(xiv) Provisions for experiment and subject information tools to save the required data;

(xv) Capability of playing back the loaded data;

(xvi) Capability to calculate Cardiac Index by using the dzt, base impedance, ECG signals, and a subject's configuration file;

(xvii) Capability to calculate Cardiac Index by using different types of formula and detecting the required points on dzt signal.

(xviii) Capability to perform automated venous occlusion plethysmography blood flow analysis and calculation;

(xix) Capability to load multi-output ASCII files collected in Tilt-table experiments;

(xx) Capability to display a selected window for analysis with the calculated point and the capability of deleting and inserting new points for Cardiac Index and blood flow calculation;

(xxi) Capability to reformat the output file into other file formats to be used as an input to statistical analysis packages;

(xxii) Capability to carry out user-defined statistical analysis on the output file;

(xxiii) Capability to detect and save all the min and max values for 'A' wave, 'C' wave, and 'O' wave in differentiated impedance cardiogram (dzt). In addition, it detects the 'B' and 'X' points in the dzt signal.

(xxiv) Detecting the ear-opacity signal peaks and valleys using customized adaptive peak detection technique and software;

(xxv) Filtering out the high frequency noise components embedded in ear-opacity signals;

(xxvi) Displaying the history of calculated ear-pulse signal amplitude against the corresponding Gz and blood pressure signals;

(xxvii) Saving calculation results in ASCII format that could be used as an input to statistical analysis packages, etc.

The current project (referred herein as Phase 4 of the development proces) adds the following features and capabilities:

(i) ASCII data files that contain multiple centrifuge or tilt-table profiles can be now loaded into G-DAP and sub-divided into single-profile data files. Previously, a single-profile data file could only contain one typical +G transition or Push-Pull transition. In the new program, a single-profile data file is also able to contain multiple atypical G-transitions for which the program automatically identifies all 'corner' and 'peak' points;

(ii) In the new program, the number of reference points (including corner, peak, and user-defined inserted points) to be associated with a G profile is no longer limited. Physiological indices are computed on all reference points associated with a G profile;

(iii) Beat-by-Beat Heart Rate Display has been implemented. The new program includes a plot of heart-rate wave, with reference points, in the calculation results;

(iv) Diastolic Blood Pressure Values have been implemented. The new feature, including C software and GUI has been implemented to show diastolic values for blood pressure and opacity pulse;

(v) Distinction between opacity and opacity pulse has been implemented. Previously, reference points were on the ear opacity only. The new program displays reference points on the ear opacity pulse too.

Table of contents

ABSTRACT i

EXECUTIVE SUMMARY iii

TABLE OF FIGURES viii

1 INTRODUCTION 1

1.1 System Analysis 1

1.2 Features and Capabilities of G-DAP Package 3

1.2.1 Features of G-DAP Package Developed in Phase 1 3

1.2.2 Features of G-DAP Package Developed in Phase 2 5

1.2.3 Features of G-DAP Package Developed in Phase 3 6

1.2.4 Features of G-DAP Package Developed by Current Project (Phase 4) 7

2 SYSTEM REQUIREMENTS 9

3 INSTALLATION 10

4 G-DAP CD CONTENTS 10

5 HOW TO RUN THE ACCELERATION (GZ) DATA ANALYSIS PACKAGE "G-DAP" 12

6 SETUP WINDOW 14

7 UTILITIES 20

7.1 File Tagging 20

8 TASK MANAGER 25

8.1 SWAP 26

8.2 PLAYBACK 27

8.3 LabVIEW Features (Signal Processing and Statistical Analysis) 28

8.4 Cardiac Index, Blood Flow, and Opacity Options 32

8.5 G-DAP (The Acceleration /Gz/ Data Analysis) Option 32

8.5.1 Blood Pressure and ECG Calculation 33

8.5.2 Acceleration Profile 36

8.5.3 G-DAP Reference Points & Modification 38

8.5.4 Calculation Configuration (Calculations of Physiological Indices) 40

9 REFERENCE POINTS DEFINITIONS 43

9.1 Physiological Variables 45

9.2 Calculation Delay 45

9.3 Calculation Duration 45
9.4 Calculation Type 46
10 EXAMPLES 48
11 G-DAP CALCULATION RESULTS 50
12 CARDIAC INDEX & BLOOD FLOW CALCULATION TOOLBOX 54
13 OPACITY TOOLBOX 65
14 FLOWCHART OF OPACITY ALGORITHM AND EXAMPLES 74

Table of figures

Figure 1. G-DAP Main Window 13
Figure 2. About G-DAP Help Window 14
Figure 3. G-DAP Setup Window 15
Figure 4. Loading file window 16
Figure 5. Default Subject's setup 16
Figure 6. Setup window for loading file configuration 17
Figure 7. File loading configuration 18
Figure 8. Data file loading 19
Figure 9. Loaded data file 19
Figure 10. G-DAP Utilities window 20
Figure 11. File tagging window 21
Figure 12. File tag-loading window 22
Figure 13. Plotted loaded file 22
Figure 14. Zooming the loaded data file 23
Figure 15. Selected window 23
Figure 16. File tagging output file (saved data) 25
Figure 17. Task Manager window 25
Figure 18. G-DAP SWAP analysis window 26
Figure 19. Expanded SWAP window 27
Figure 20. Play Back window 28
Figure 21. Labview Features window 29
Figure 22. Analysis window 30
Figure 23. Digital signal processing window 31
Figure 24. Statistical analysis window 32
Figure 25. Blood pressure & ECG window 33
Figure 26. BP & ECG calculation window 34
Figure 27. ECG sample window 34
Figure 28. Calculated Systolic and diastolic pressures, and R-R interval 35
Figure 29. Systolic and diastolic pressure of opacity pulses 36
Figure 30. Acceleration profile 37
Figure 31. Selected signal for analysis 38
Figure 32. Acceleration profile setup window 39
Figure 33. Calculated Gz reference points (P1 - P7) 39
Figure 34. Gz reference points definition help window 40

Figure 35. Calculation configuration window 41
Figure 36. Loading configuration file 42
Figure 37. Calculation configuration setup window 42
Figure 38. Calculation configuration matrix 43
Figure 39. Gz defined reference points 44
Figure 40. Instant mode calculation for blood pressure 47
Figure 41. Scope mode calculation for ear opacity signal 48
Figure 42. Calculation window 50
Figure 43. G-DAP calculation results 51
Figure 44. G-DAP calculation results "Blood Pressure" 52
Figure 45. Systolic and diastolic pressures of opacity pulses at P1 52
Figure 46. G-DAP calculation results (blood pressure & ear opacity) 53
Figure 47. Saving calculation results window 53
Figure 48. G-DAP output file (EXCEL format) 54
Figure 49. Cardiac Index & Blood Flow Calculation 55
Figure 50. Definition Z0 window 56
Figure 51. Plotted ECG & Dzt signals 57
Figure 52. Calculated points for ECG & Dzt signals 58
Figure 53. Calculated results window 59
Figure 54. Cardiac Index and Blood flow calculation output file 60
Figure 55. Systolic/Diastolic and R-R interval calculation 61
Figure 56. File saving window 62
Figure 57. PLETHYSMOGRAPH slope calculation 63
Figure 58. Labview zoom utility 63
Figure 59. PLETHYSMOGRAPH slope calculation 64
Figure 60. ASCII data file output 65
Figure 61. Signal display window 65
Figure 62. Channel configuration window 66
Figure 63. Loaded data display window 67
Figure 64. Opacity filter utility window 67
Figure 65. Opacity filter setting parameters window 68
Figure 66. User's defined calculation parameters 68
Figure 67. Calculated peaks and valleys for blood pressure and opacity signals 69
Figure 68. 3D analysis plot utility 70
Figure 69. 3D analysis surface plot 70
Figure 70. 2D analysis plot 71

Figure 71. Acceleration profile window 72
Figure 72. Gz reference points modification window 72
Figure 73. Calculation configuration window 73
Figure 74. Calculation results 73
Figure 75. Flowchart of G-DAP-3 Algorithm for Calculating Amplitude of Ear Opacity Pulse 74
Figure 76. Identification of peaks and valleys of ear pulse signal during resting period 75
Figure 77. Identification of peaks and valleys of ear pulse signal during G run period 76

1 INTRODUCTION

1.1 SYSTEM ANALYSIS

For completeness, this section explains advantages of the Labview-based custom-designed physiological data analysis package (G-DAP) as compared to physiological data analysis packages available commercially (e.g., Acqknowledge). Based on the extensive investigation performed by the ALSS personnel, it has been concluded that the commercial packages possess a number of desirable features, yet their closed design architecture does not allow the customizations of GUI and implementation of special data analysis options required for ongoing and future ALSS projects. Hence their overall operation becomes too time-consuming and awkward in the sense that it does not readily allow for the performance of consistent and accurate data analysis across a population of test subjects. Furthermore, non-Labview based data analysis packages do not allow synergetic co-operation with Labview-based DAQ software and hardware implementation planned by ALSS.

The table below shows a brief comparison between the custom-design G-DAP package and commercial packages in the point form. The table has been designed to reflect major requirements of the ALSS users, such as unique data analysis features required by ALSS, Graphical User Interface (GUI) design, ease of customization and expansion, compatibility with Labview-based DAQ in the future, etc. As a general comment, it has to be noted that Labview is very popular in the research and industrial community thanks to its powerful DAQ and analysis features, as well as the compatibility with most of DAQ-related hardware available on the market. ALSS has been successfully using DAQ software based on previous generations of Labview for many years.

In conclusion, the Labview based G-DAP package is viewed as considerably more suitable for resolving a broad spectrum of current and future requirements posed by ALSS work than the commercial software packages available on the market. Last but definitely not least, the Labview-based G-DAP package might potentially constitute a long-term solution for ALSS, because it will readily and naturally evolve and expand

by being modified based on the ALSS users' future needs. For instance, it will be possible to design new macros that would automatically calculate all the parameters and indices of interest for ALSS Experimental Protocols and required test conditions (e.g., the ongoing Push-Pull data analysis). The availability of such an automatic analysis feature is expected to greatly assist ALSS researchers and save a very significant amount of time in the process of data analysis. This is definitely not the case with the commercial data analysis packages currently available on the market.

Functionality and Features	**Labview-based G-DAP Package**	**Commercial Packages**
Software Design Architecture	Open	Closed
Ease of Customization and Adaptation	High	Low
Specialized Analysis Options required by ALSS	Available	None
Implementation of new code & macros	Very good	N/A
Compatibility with other software & hardware	Very good	Bad
Math Functions, Statistics, etc.	Very good	Good
I/O capabilities (Input/Output)	Excellent	Very good
Compatibility with planned Labview-based Data Acquisition s/w and h/w (DAQ)	Excellent	Low
Quality of GUI	Excellent	Good
Flexibility of GUI	Excellent	Low

G-DAP (The Acceleration (Gz) Data Analysis Package) is a program for custom defined analysis of physiological data. G-DAP has several different applications. For example, it can be used for playing back data acquired in the course of a physiological experiment, providing signal processing features for further analysis of the specific data, automatic calculation of predefined or custom defined physiological indices for acceleration physiological research.

The overall package is designed based on open architecture principles. New functions can be readily added for more complicated and comprehensive analysis. The User's Guide, which starts from Section 2 of this report, will be updated for any future modifications.

1.2 Features and Capabilities of G-DAP Package

The original G-DAP package has been developed in three phases. All of the desired features and capabilities implemented in Phases 1-3 and outlined in sections 1.2.1-1.2.3, respectively, are available in the final version of G-DAP package installed at DRDC-TORONTO. The current project (referred herein as Phase 4) implements a number of advanced features and capabilities that are explained in section 1.2.4.

1.2.1 Features of G-DAP Package Developed in Phase 1

This section describes features of Labview based custom-designed physiological data analysis package (G-DAP) developed in Phase 1 of this project. The package has been designed to satisfy a set of basic specific requirements pertinent to the ACAP program. In general, as defined in the previous subsection, the idea behind the package is to eliminate (or reduce) the amount of manual operations (e.g., the selection of data regions of interest) towards automatic analysis of selected regions throughout an experimental data files. In general, the initial G-DAP package has been provided with the following features and capabilities:

(i) Capability of loading binary and ASCII files with predefined formats;

(ii) Display of the loaded data in strip chart format (the maximum number of channels on each display should be set based on the size of the monitor);

(iii) The data strips can be marked (using an appropriate event marker) by the user;

(iv) Capability of exporting the loaded and processed data from a pre-defined format to the spreadsheet format (Excel);

(v) Default selections across all channels in correspondence with a window defined by the user for a single channel;

(vi) Capability of printing the selected waveforms to a postscript printer or screen dump the selected waveforms (plot) into other applications (e.g. MS Word or MS Power Point);

(vii) Availability of SWAP-like features such as Zoom, Front, Back, Redisplay. In general, most of the SWAP commands are built using Labview. The most important part of the SWAP is the SPAN command that can be used to analyze a block of data. All features of SPAN command are implemented. Moreover, the capability of saving and sorting the selected analyzed data with sorting the collected data based on time stamps is implemented;

(viii) Capability of calculating systolic, diastolic, and RR interval for blood pressure and ECG waveforms (automated blood pressure analysis) for each heartbeat in the file;

(ix) Capability of user-defined Gz window with different timing events (Push-Pull or Pull) for extracting, analyzing, and saving the other channels data to the spreadsheet format;

(x) Capability of editing the calculated Gz reference points interactively;

(xi) Capability of choosing the Gz profile based on the experimental facility used (e.g., in flight, DRDC-TORONTO centrifuge, Veda centrifuge, Tilt-table);

(xii) Implementation of Labview based analysis routines such as FFT, Spectrum, Filtering, and Correlation;

(xiii) Provisions for user-defined channel configuration for maximum of 50 channels;

(xiv) Provisions for experiment and subject information tools to save the required data;

(xv) Capability of playing back the loaded data;

1.2.2 Features of G-DAP Package Developed in Phase 2

This subsection reports on the features and capabilities implemented for G-DAP Package in Phase II, including a new Graphical User Interfaces (GUI) and scientific software for blood flow analysis and calculation of related indices.

Phase II has addressed the development and implementation of new features for G-DAP software in general, and blood flow analysis with the calculation of related indices based on different methods of calculations in particular. Also, it has addressed the implementation of a new graphical user interface for blood flow analysis, as well as the development of a customized statistical routine that could be used by G-DAP users. Overall, G-DAP-II package possesses the following advanced features:

(i) Capability to calculate Cardiac Index by using the dzt, base impedance, ECG signals, and a subject's configuration file;

(ii) Capability to calculate Cardiac Index by using different types of formula and detecting the required points on dzt signal.

(iii) Capability to perform automated venous occlusion plethymography blood flow analysis and calculation;

(iv) Capability to load multi-output ASCII files collected in Tilt-table experiments;

(v) Capability to display a selected window for analysis with the calculated point and the capability of deleting and inserting new points for Cardiac Index and blood flow calculation;

(vi) Capability to reformat the output file into other file formats to be used as an input to statistical analysis packages;

(vii) Capability to carry out user-defined statistical analysis on the output file;

(viii) Capability to detect and save all the min and max values for 'A' wave, 'C' wave, and 'O' wave in differentiated impedance cardiogram (dzt). In addition, it detects the 'B' and 'X' points in the dzt signal.

G-DAP-II software has been tested on tilt-table experimental data.

1.2.3 Features of G-DAP Package Developed in Phase 3

This subsection summarized Phase 3 of the development and implementation of new features for G-DAP Acceleration Data Analysis software package in general and analysis of ear-opacity signals in particular. Ear opacity signal analysis implemented in G-DAP Version 3 is based on an adaptive peak detection algorithm. The development and implementation of a new user interface for ear-opacity signal analysis have also been performed. The new software enables a user to process, filter, display, and analyze ear-opacity signals acquired in physiological studies. The new package possesses a number of desirable capabilities:

(i) Detecting the ear-opacity signal peaks and valleys using customized adaptive peak detection technique and software;

(ii) Filtering out the high frequency noise components embedded in ear-opacity signals;

(iii) Displaying the history of calculated ear-pulse signal amplitude against the corresponding Gz and blood pressure signals;

(iv) Saving calculation results in ASCII format that could be used as an input to statistical analysis packages, etc.

1.2.4 Features of G-DAP Package Developed by Current Project (Phase 4)

The project addresses the development and implementation of new features for G-DAP software as needed to support advanced acceleration research undertaken by Aircraft Life Support Sector (ALSS) of DRDC-Toronto. Also, the project augments G-DAP user interfaces to support the implementation of the new capabilities. In addition to its existing features, the modified G-DAP package possesses the following advanced features:

(i) ASCII data files that contain multiple centrifuge or tilt-table profiles can be now loaded into G-DAP and sub-divided into single-profile data files. Previously, a single-profile data file could only contain one typical +G transition or Push-Pull transition. In the new program, a single-profile data file is also able to contain multiple atypical G-transitions for which the program automatically identifies all 'corner' and 'peak' points:

a. The 'corner' points are the starting or ending points of 'plateau' in G profiles. Therefore there are two 'corners' associated with each 'plateau' of 1 sec or more in duration (refer to the schematics on the next page).

b. When the duration of a 'plateau' is less than 1 sec., only one point dubbed 'peak' point is identified (refer to the schematics on the next page).

c. In order to reliably identify 'corner' or 'peak' points, two conditions are imposed on G profiles in the new program:

- The difference in G level from one 'plateau' to the next 'plateau' must be greater than 3.5 times the noise level in G-level measurement. The default is as follows: the variation from one 'plateau' to the next 'plateau' must be greater than 0.35G or smaller than negative 0.35G (this threshold depends on the noise level in G-level data file; typically the noise level in centrifuge G-profile measurements is less than 0.1G). For cases of clean G-level measurements, such as tilt-table experiments, the

user is given the option to input the value of minimum variation in G from one 'plateau' to the next 'plateau'*.

- The onset rate in transition from one 'plateau' to the next 'plateau' must be greater than 3.5 times of the noise level in onset rate computation. The default is as follows: the onset rate in transition from one 'plateau' to the next 'plateau' must be greater than 0.2G/sec or smaller than negative 0.2G/sec. For cases of clean G-level measurements, such as tilt-table experiments, the user is given the option to input the value of minimum onset rate from one 'plateau' to the next 'plateau'.

(ii) In the new program, the number of reference points (including corner, peak, and user-defined inserted points) to be associated with a G profile is no longer be limited. Physiological indices are computed on all reference points associated with a G profile.

(iii) Beat-by-Beat Heart Rate Display is implemented. The new program includes a plot of heart-rate wave, with reference points, in the calculation results.

(iv) Diastolic Blood Pressure Values are implemented. The new feature, including C software and GUI is implemented to show diastolic values for blood pressure and opacity pulse.

(v) Distinction between opacity and opacity pulse is implemented. Currently, reference points are on the ear opacity only. The new program will display reference points on the ear opacity pulse too.

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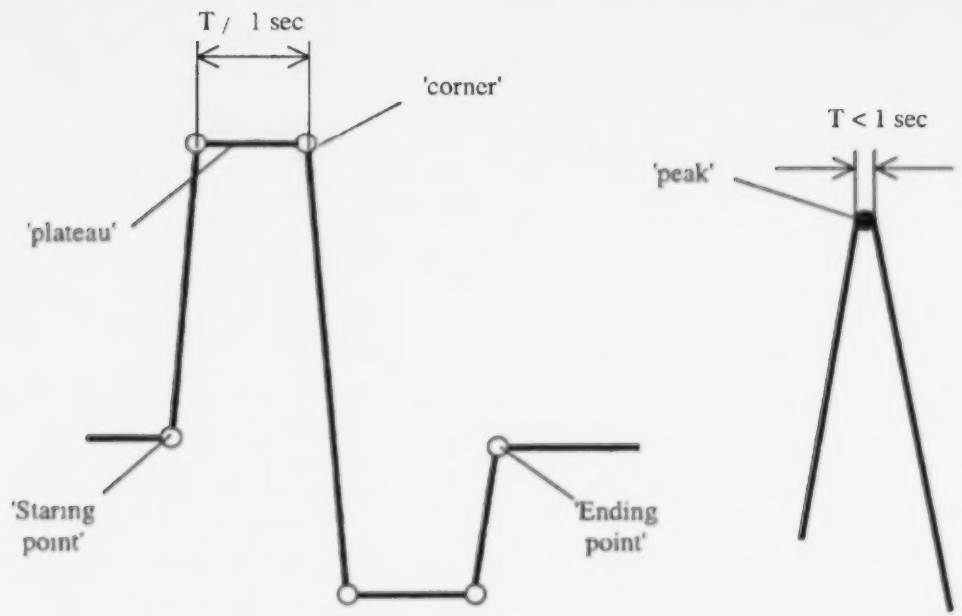
* for cases of noisy G-level measurements, such as in flight experiments, the user can use this option to input a suitable "increased" value of minimum variation in G from one 'plateau' to the next 'plateau' so that the 'corner/peak' point identification algorithm can work reliably on noisy data



Schematics for definition of 'Corner' and 'Peak' points in G profiles

2 SYSTEM REQUIREMENTS

G-DAP requires Microsoft® Windows™ 95/98, NT[1] or 2000. In general, the following configuration is suggested as minimum system requirements for running G-DAP.

- Windows 95/98, NT, or 2000.

---

[1] It should be mentioned that the runtime version of G-DAP works only under Windows NT and Windows 2000. For Windows 98, the source code under LabVIEW™ should be used. Runtime versions of G-DAP will run under Windows 98 when Nation Instruments fixes the current problems with running runtime versions of LabVIEW™ software under Windows 98.

- 100 MB of disk storage for source code version.
- 32 MB of RAM with a Pentium Processor.
- Service Pack 3 or later for Windows NT.
- Video driver with minimum capability to be configured for at least 256 colors with 800 x 600 pixel resolution.

3 INSTALLATION

Be sure that Windows 95/98 or NT is installed and running properly before installing the G-DAP. For source code version, you need to install LabVIEW™ Version 5.1 or later (Ref. LabVIEW™ Version 5.1 Installation Guide). To install G-DAP, follow these steps:

1. Make sure that LabVIEW™ Version 5.1 or later is installed.
2. Insert G-DAP CD into your CD driver.
3. Select your CD driver through ***My Computer*** icon.
4. Select G-DAP folder on the CD (for source code version).
5. Select G-DAP-RUN folder on the CD (for runtime version).
6. Copy the selected folder on your hard drive (e.g., C:\ , D:\ , ..).
7. Create a shortcut of G-DAP-RUN file for runtime version or G-DAP-RUN.VI for source code version.
8. Copy the shortcut to your Windows Desktop.
9. To run the G-DAP double click on the G-DAP shortcut icon.

4 G-DAP CD CONTENTS

After Installation your G-DAP directory should contain the following subdirectories in addition to the files and directories listed in your system.

\.	G-DAP LabVIEW source codes.

\Gzreference	Gz reference points (P1-P7) for calculation of indices.
\GzTagging	Calculated reference points for file tagging.
\Calindices	Output files of calculations of specific physiological indices based on user defined configuration.
\Calconfig	Configuration files for calculating user defined indices.
\Data	Experimental data files.
\Dataconfig	Configuration files. It contains the channel configuration for loading data file.
\Subject	Subject information files. These files will be used to generate a header for the output files.
\Cfiles	C files subroutines implemented in the G-DAP.
\User's Guide	User's Guide document for G-DAP.
\Cal-Output	Output files subdirectory.

In general, the G-DAP directories contain different type of files such as:

*.CPP	C++ files for analysis routines and I/O
*.VI	LabView™ source code file
*.DAT	Data file
*.SUB	Subject information data file
*.CFG	Channel configuration file for loading the data file
*.ACA	Analysis configuration file for user defined analysis
*.IND	Output file for calculated indices
*.DOC	Word document file (e.g. User's Guide)
*.OBJ	C++ object file
*.EXE	Runtime file

5 How to Run The Acceleration (Gz) Data Analysis Package "G-DAP"

To run the G-DAP, double click G-DAP icon. If you receive any error messages it indicates that the installation of the package was not performed properly. In any event of getting error messages, it is recommended to write down the error message for tracking and fixing the error.

If the G-DAP is installed properly, the G-DAP main window will be open by double clicking G-DAP icon. This window navigates the user through different applications of the G-DAP package. As mentioned before, the G-DAP package was designed in a way that it is readily expanded for more detailed analysis of physiological data, therefore, some of the function buttons do not operate in the current version of the package. Therefore if users find certain button do not respond, it means this feature is not implemented in this version of G-DAP.

Figure 1 shows the main window of G-DAP package. All buttons are described in the figure. In general, to make it easy to open or save files in the proper directories, the user needs to define the location of the G-DAP package in the hard drive (e.g., C:\, D: , etc.). To select a different hard drive, click the letter to show a list of hard drives in the computer or left side arrows to change the hard drive.

Figure 2 shows the general information about G-DAP software that can be viewed by pressing the About G-DAP button on main window. Users should always start with setup task first. By pressing the SETUP button, the SETUP window will be displayed (see Figure 3). The G-DAP will not execute other tasks without completing the setup steps.

When the setup task is completed, the user can choose any of the features in TASK MANAGER or UTILITIES windows. Clicking the EXIT button will exit from the G-DAP program. For the source code version that runs under LabVIEW software, after clicking on exit, the user needs to close the window by clicking the right upper corner of the main window.

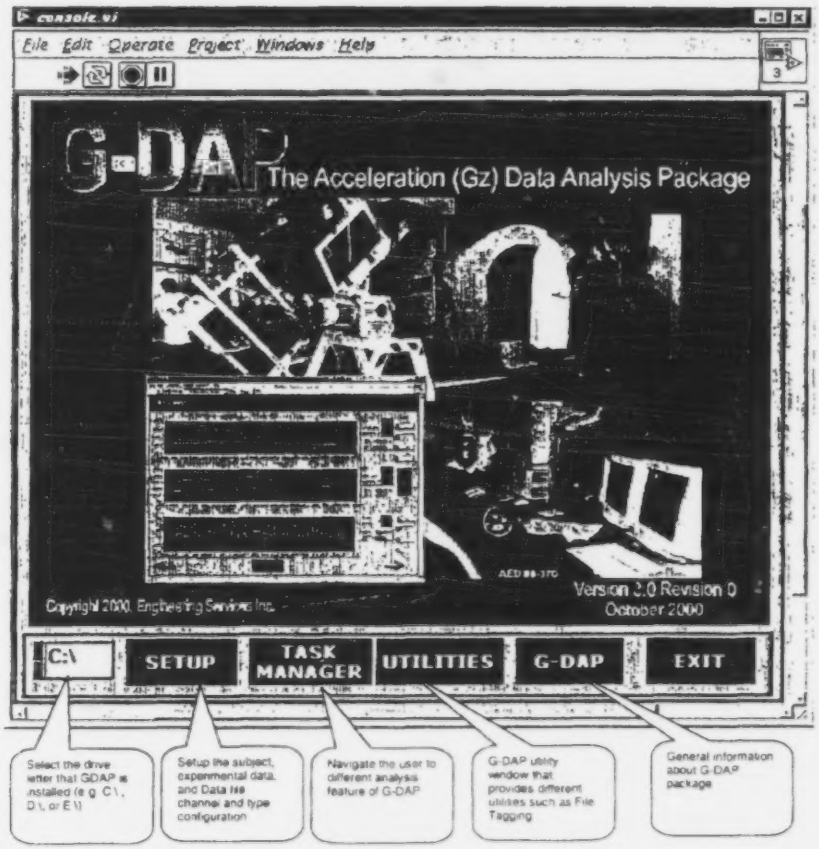

File Edit Operate Project Windows Help
G-DAP
The Acceleration (Gz) Data Analysis Package
Copyright 2000, Engineering Services Inc.
Version 2.0 Revision 0
October 2000
C:\
SETUP
TASK MANAGER
UTILITIES
G-DAP
EXIT
Select the drive letter that GDAP is installed (e.g. C:\, D:\, or E:\)
Setup the subject, experimental data, and Data file channel and type configuration
Navigate the user to different analysis feature of G-DAP
G-DAP utility window that provides different utilities such as File Tagging
General information about G-DAP package

Figure 1. G-DAP Main Window

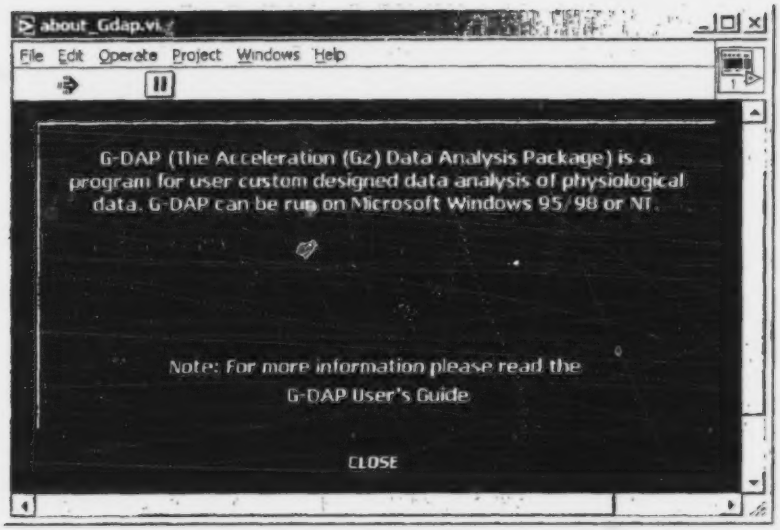

about_Gdap.vi
File Edit Operate Project Windows Help
G-DAP (The Acceleration (Gz) Data Analysis Package) is a program for user custom designed data analysis of physiological data. G-DAP can be run on Microsoft Windows 95/98 or NT.
Note: For more information please read the G-DAP User's Guide
CLOSE

Figure 2. About G-DAP Help Window

6 SETUP WINDOW

Using this window (Figure 3), the user can enter the information about the experimental protocol and subject information. Moreover, the configuration and the type of the data file for analysis needs to be defined in this window. Through this window the user can define all the required parameters for the program. Users can input all the information about the subject and experimental protocol by clicking appropriate boxes, and typing the information. If there are any comments, it can be written in the comment box. After completing the information the user can save this subject information by clicking on the SAVE button. As indicated in Figure 4, the program automatically assigns a specified file type to saved file (*.SUB[2]).

[2] There is no difference between lower or upper case for the file types.

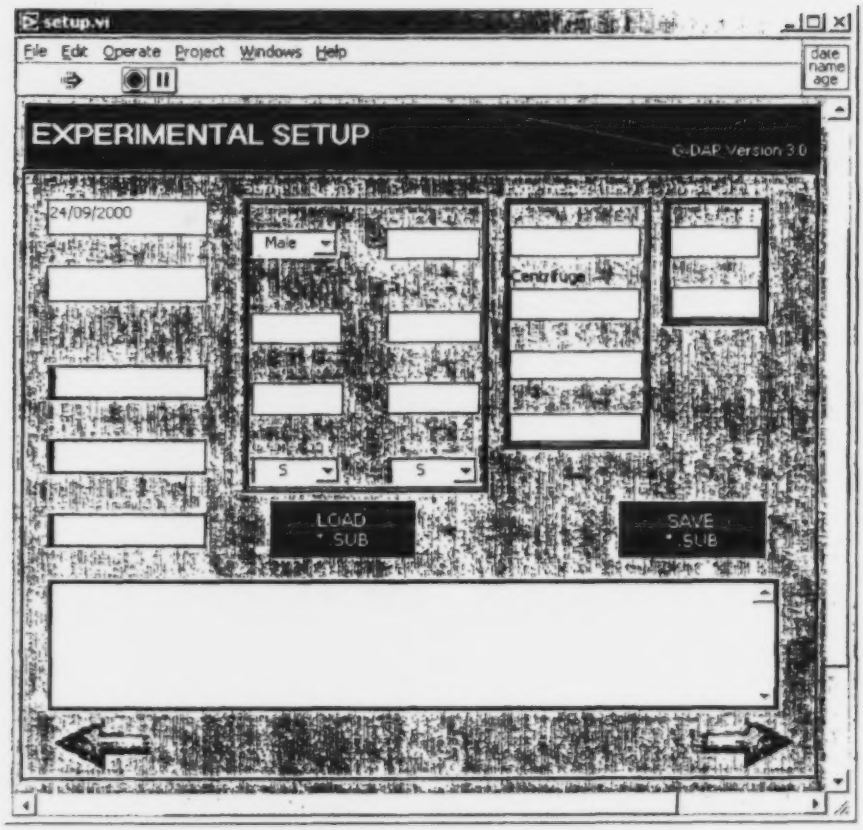


Figure 3. G-DAP Setup Window

To save the subject information, the user needs to select or type a file name. A file type of .sub will be automatically used for this file. Therefore all the files with extension *.sub* are the subject information data. Users can also input all the information from an existing .sub file by pressing the LOAD button and opening the subject file (see Figure 4). A subdirectory in the G-DAP program is assigned to the subjects' setup file. By saving the subjects' setup file in this directory, it is much easier to look for a subject's setup file for loading. To go to the next step of the SETUP just press NEXT arrow in Figure 5. In general, the BACK and NEXT arrows can be used for navigating and switching among different windows. Finally, it should be mentioned that there are no minimal compulsory entries for this setup window, but it is recommended to load at least the *default.sub*.

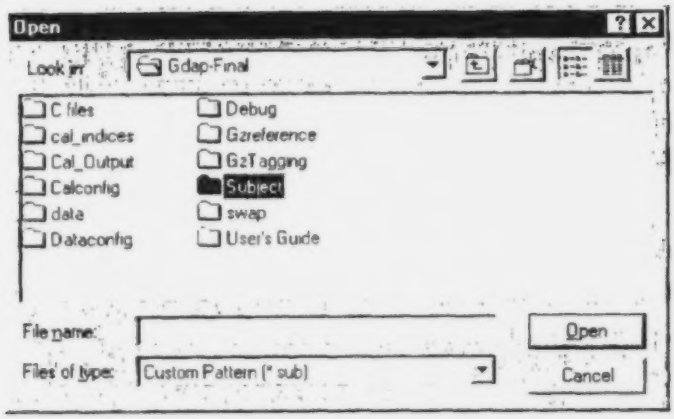


Figure 4. Loading file window

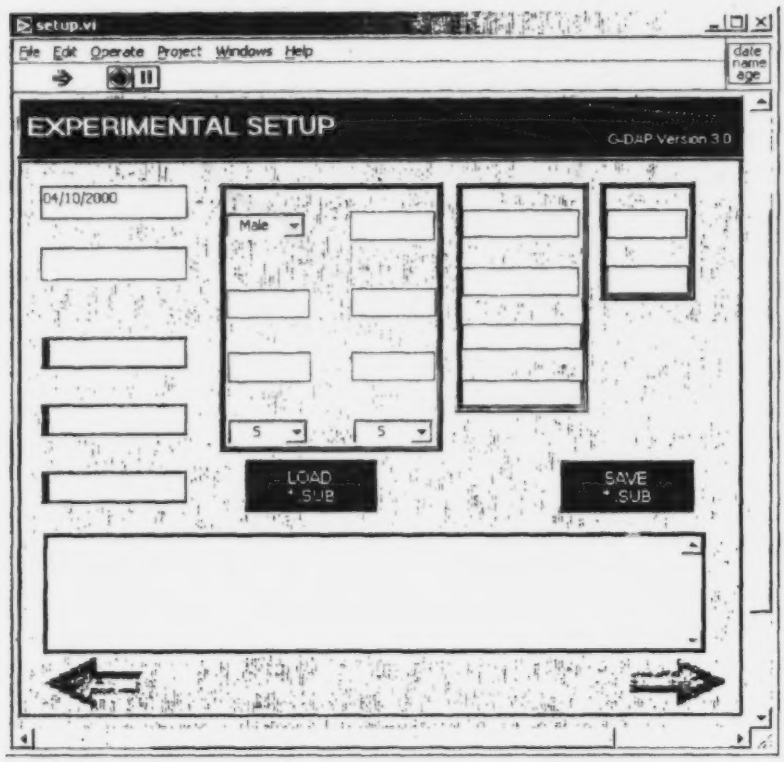


Figure 5. Default Subject's setup

To go to next setup screen just press the arrow NEXT. The configuration setup for loading data file will be opened. Figure 6 shows the data file-loading configuration.

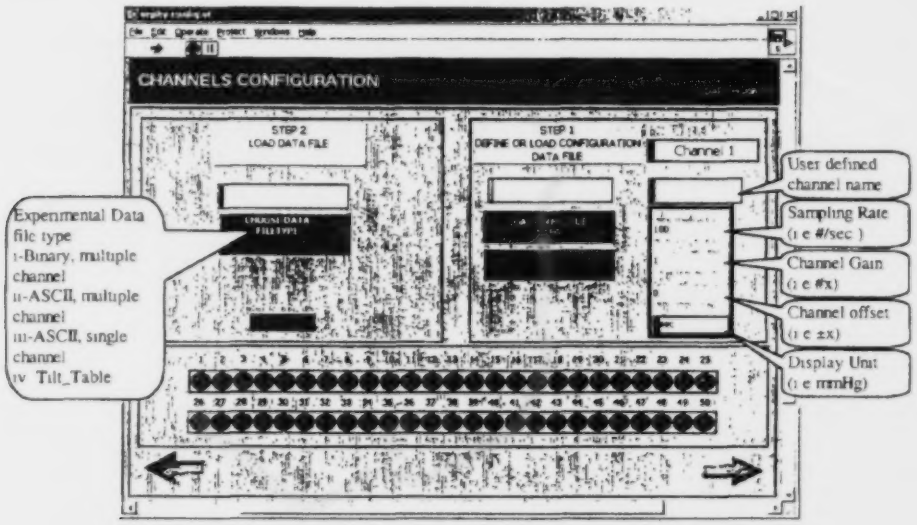


Figure 6. Setup window for loading file configuration

The channel configuration window can be used for configuring the types of data file and also the channels that a user wants to load in the data file. In general, a multi-ascii file with 50 channels (50 columns) of data can be loaded. Also, a user can load a single-channel-ascii file or multi-channel binary file. The user needs to define the sampling rate, gain, offset, and the name of each channel before loading the data file (STEP 1). To activate each channel, just press the corresponding button numbered 1-50. By activating a channel (pressing the corresponding button) the color of the pressed button will change to light green. When the channel configuration is finished, the user can save this configuration for future analysis. By pressing the SAVE CONFIG button the user can save the configuration by typing a name for the configuration file. The G-DAP automatically assigns a .cfg file type to the saved file. Also, to organize the files, a subdirectory in G-DAP is available for saving or loading configuration files (Dataconfig subdirectory). If the channel configuration is already defined, the user can load the configuration file by pressing LOAD CONFIG button. Figure 7 shows the loading configuration window.

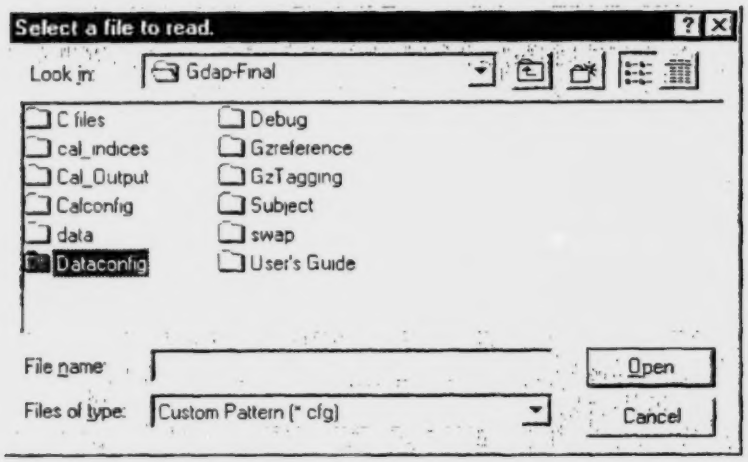


Figure 7. File loading configuration

When the channel configuration is done or loaded, the data file can be loaded (STEP 2). As was mentioned before, a user can choose three different types of data file for loading. Figure 8 shows the data file-loading window. The user needs to select the data file in this window. By selecting the data file, the data file will be loaded based on the channel configuration loaded (or prepared) in STEP 1. Figure 9 shows the loaded data file window. The only channels that are loaded for this configuration are channels 3,4,5,6,9,16, and 18. After completing setup task and pressing the arrow NEXT, it will return to the main window. The user can choose task manager or utilities command in the main window.

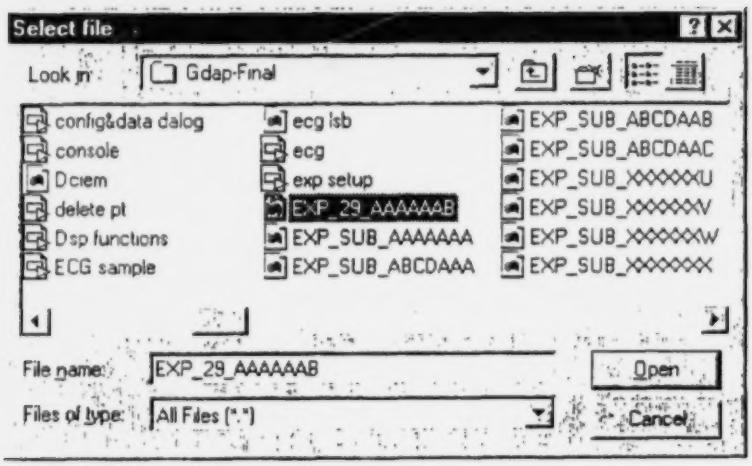


Figure 8. Data file loading

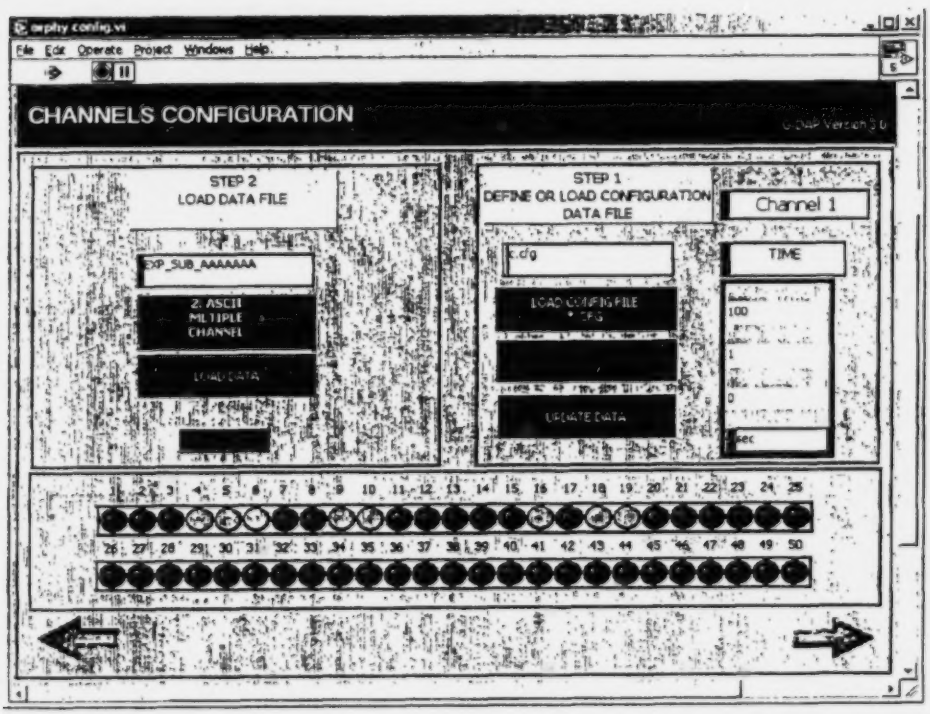


Figure 9. Loaded data file

7 UTILITIES

7.1 FILE TAGGING

For the current version of the G-DAP, there is only one command in utilities window. Figure 10 shows the utility window. The only activated feature in this window is 'File Tagging Utility'.

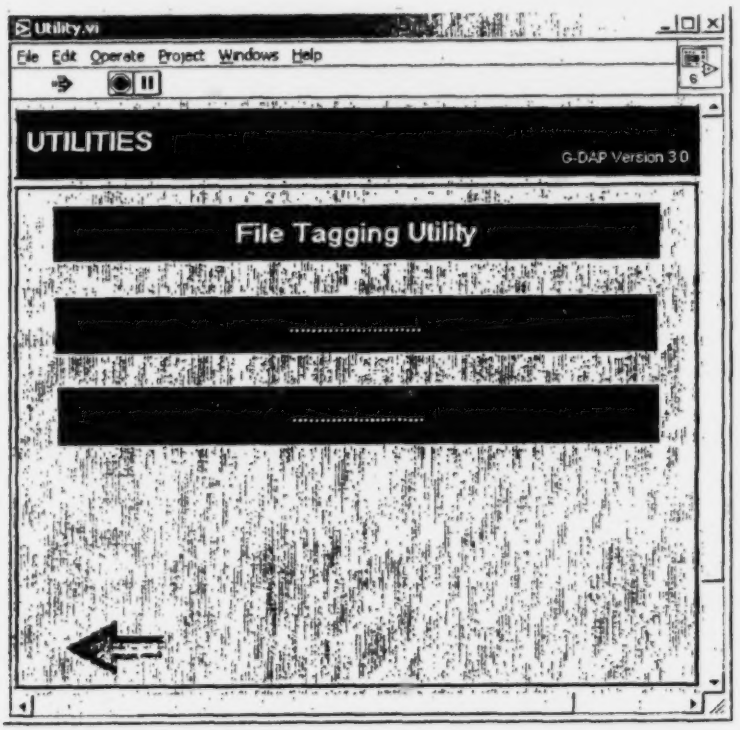


Figure 10. G-DAP Utilities window

This feature (tagging) helps the user to select a segment of a large data file and named that portion based on some sort of convention relevant to the experimental conditions using seven different letters. By convention, the file name will reflect certain characteristics of the data in the file. This feature is helpful for a user to locate certain kind of data files from their names. In general, it provides some sort of user defined file name that can be used for further analysis. Figure 11 shows the file tagging utility window. It should be mentioned that the default seven letters are set as X initially, and the user can change these just by clicking the

right mouse click on the selected factor and choose another letter. Also, the file name window on the lower left corner of the window can be changed by the user. The default file name is EXP_SUB_. The name that will be used for the segment of the data is going to be the combination of the file name and seven factors. By pressing the select button this name will be used for that segment of the data. For example, if the user presses the select button without any changes on the file name and factors, the file tag appears as EXP_SUB_XXXXXXX.

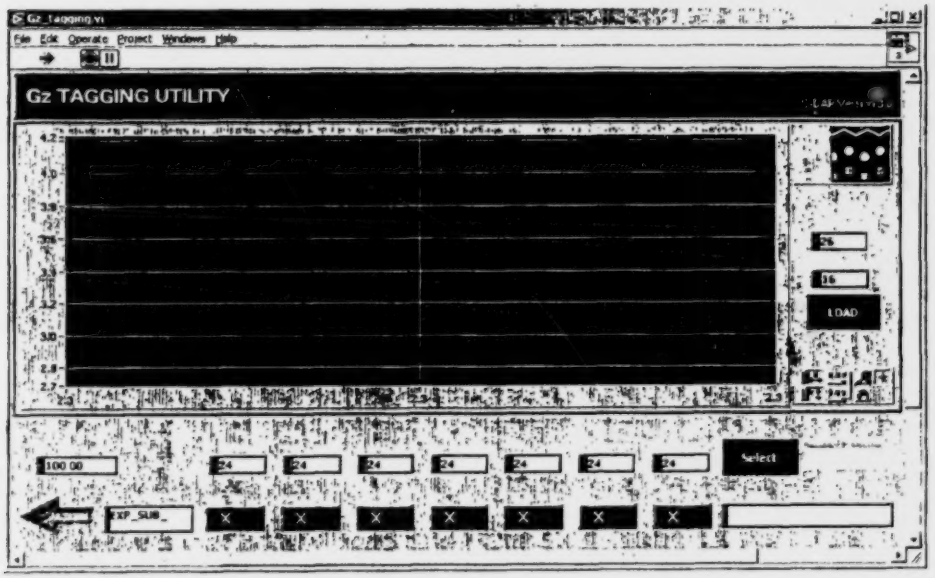


Figure 11. File tagging window

To use this utility, the user needs to define the number of channels (columns of data) existing in the data file. Also, it is necessary to define the channel number that user wants to use for the reference to select the desired window based on that one. In this utility, it was pre-assumed that the user was interested only in loading the Gz signal for tagging window. After selecting the number of channels and Gz channel number, the data can be loaded by pressing the load button (Figure 12). When a file is loaded, the status dialog shows the status of loading. When the file is loaded the Gz signal will be plotted in the plot area (Figure 13). Now the user can choose any part of the Gz signal by defining a 'selection window' on the required portion. User can use the cursor or the plot utilities located on the lower right corner of the plotting window to define a 'selection window'. By choosing

any window, the program automatically assigns a start point and an endpoint for that window (the legend and color for start and end points is shown in the right upper corner of the window) (Figure 14). Whenever a window is chosen, a file tag name needs to be assigned too. The user can choose different windows (with different file tag name) by loading a large data file. The program will save the identified window under the selected file tag names (Figure 15).

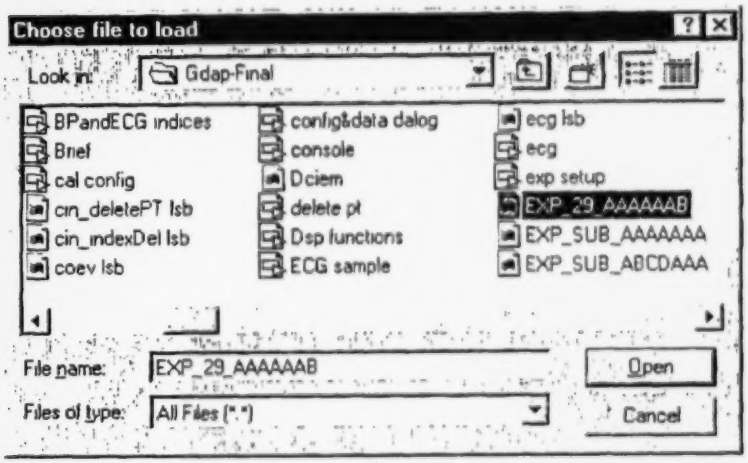


Figure 12. File tag-loading window

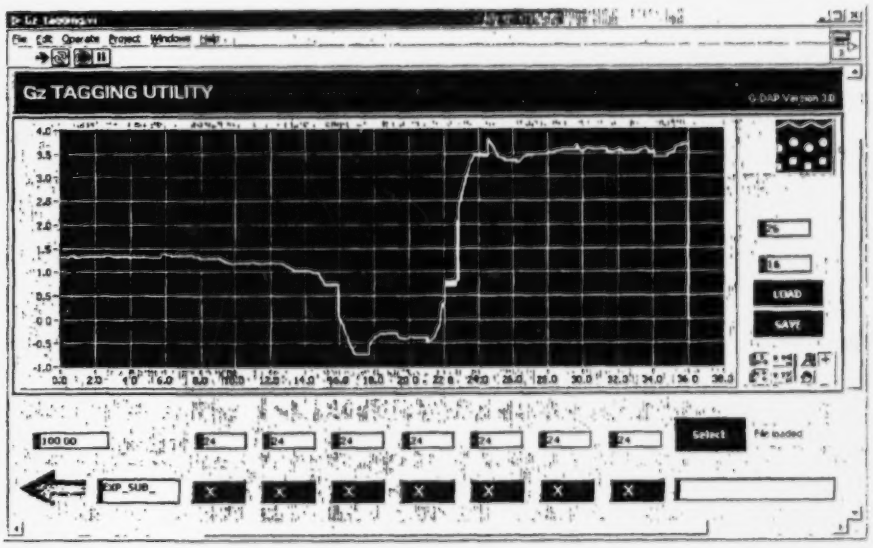


Figure 13. Plotted loaded file

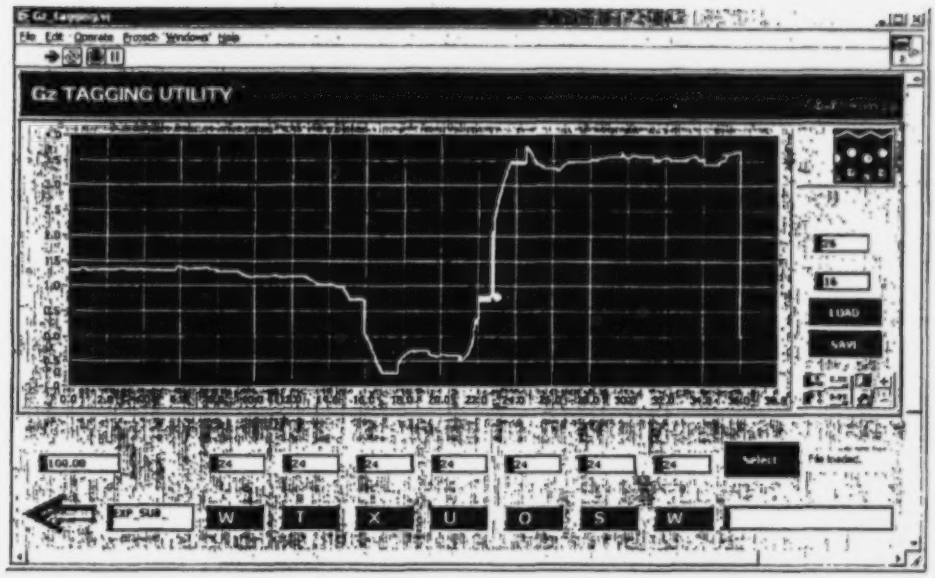


Figure 14. Zooming the loaded data file

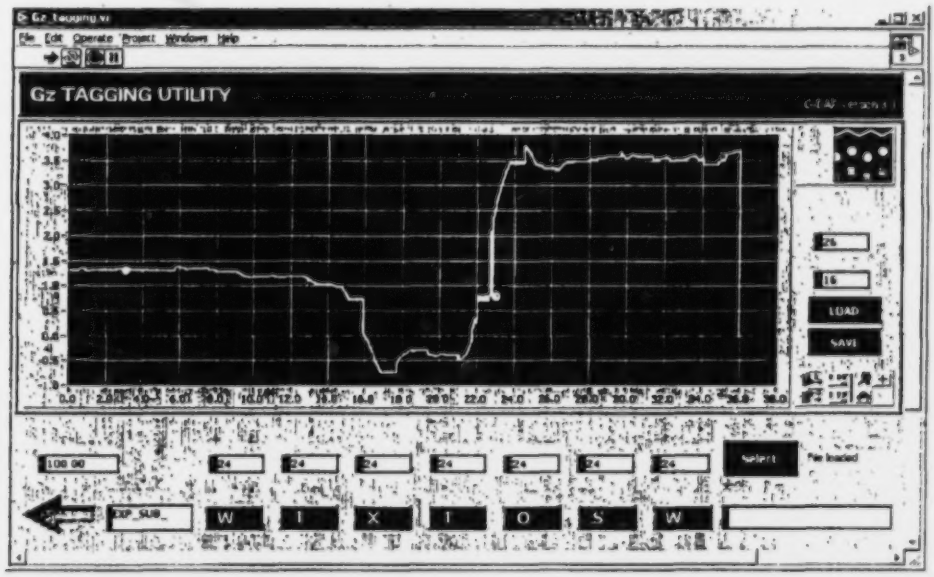


Figure 15. Selected window

As was mentioned before there are up to seven experimental factors that are represented with a single letter for defining a file tag name. The file tag name will

be a combination of file name and all seven factors. To select different factors just left click on the arrow for the selected factor. It should be mentioned that the number of levels for each factor can be defined by the user. If a user types 3 in number of factor box by clicking on the factor box the user can only choose A, B, or C letter representing one of three levels of that experimental factor. Therefore, through the factor item number the user can define the maximum number of letters that is needed for the tagging. A factor designated by X means it is not relevant in the experiment being analyzed. When the selection of tags is completed, by pressing the SELECT button, the program automatically sets the file name for the user-defined window of the selected file. At this level the selected file can be saved under the selected name by pressing the SELECT button. It should be mentioned that this utility is just for splitting the large experimental data files into short files and naming these files based on predefined naming system. Since large data files are time consuming to load, it is recommended to complete the tagging of all segments of the data file[3]. Figure 16. shows the saved files through the process of file tagging utility. Now, to analysis data, press the BACK arrow to return to main window. In the G-DAP main window the user can use the TASK MANAGER for different types of analyses. It should be mentioned that user needs to load the data file that needs to be analyzed.

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[3] In typical experiments conducted in DRDC-TORONTO up to 1999, one segment would consist of one Gz exposure (one ROR centrifuge profile) while one data file would consist of all the Gz exposures for one subject on one day. In experiments conducted after 1999, data acquired in one Gz exposure would be stored as one data file. These files can be analyzed by G-DAP, and there is no need of tagging these files.

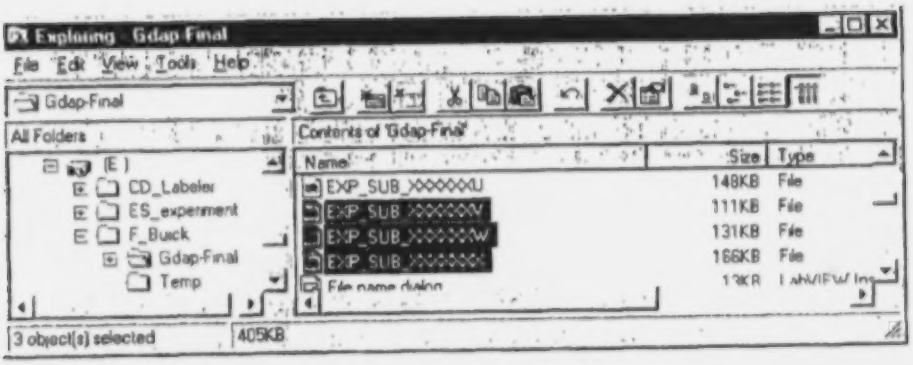


Figure 16. File tagging output file (saved data)

8 TASK MANAGER

Figure 17 shows the task manager window. Different analysis routines are implemented in this version of G-DAP. The SWAP feature is the current analysis package that was developed on the Unix platform for DRDC-TORONTO in the late 1980's. This SWAP is capable of analyzing the data using the same functions as the ones available in the original SWAP program. For the SWAP program, the data file must be a single channel ASCII file. The other tasks available in G-DAP are PLAYBACK, LABVIEW FEATURES, G-DAP, CARDIAC INDEX & BLOOD FLOW, and OTHER.

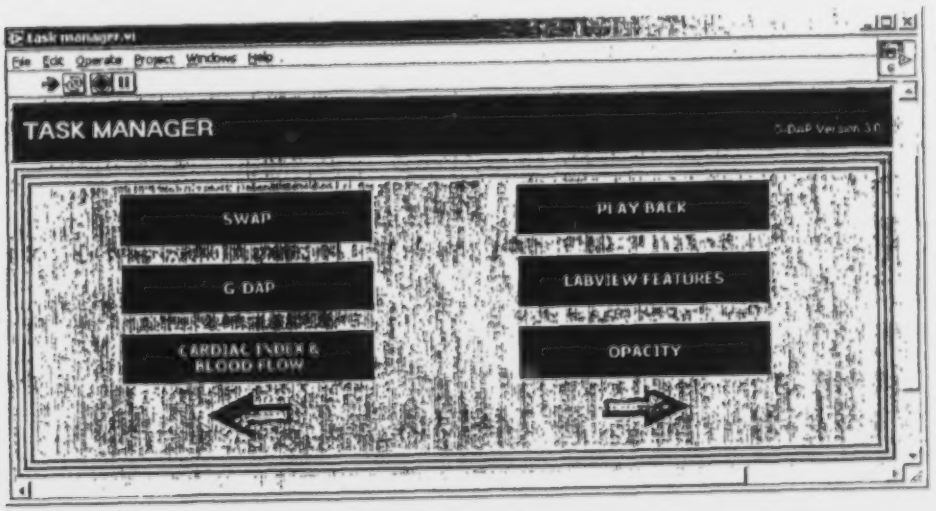


Figure 17. Task Manager window

8.1 SWAP

By clicking SWAP button, the SWAP window will provide all the analysis features available in the original SWAP program (Ref. *SWAP User's Manual "DRDC-TORONTO"*). Figure 18 shows the SWAP window. In the portion of the available plots, the user could choose any data file name (or channel name corresponds to a specific data file) for analysis. To select more than one file, hold the Shift key and click the required files. In general, a maximum of four different files can be selected simultaneously in SWAP window. All data processing functions are listed in the left lower corner of the SWAP window. They can be performed on the loaded file by pressing these buttons. These functions are identical to the functions available in the original SWAP package with more flexibility in implementation. To save any calculated data, the user needs to press SAVE button for each plot separately. Also, to show more details of the data in a display window, it can be expanded to a single display window by pressing the EXPAND button. Figure 19 shows the expanded SWAP window for single data file.

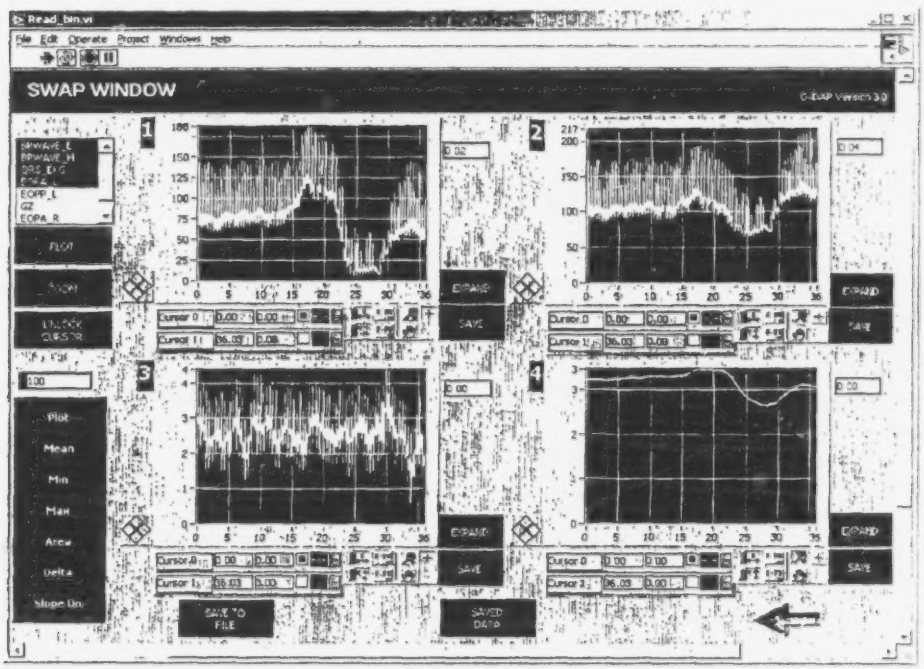


Figure 18. G-DAP SWAP analysis window

To return to the original window, just press the GENERAL button. In general, the saved data can be displayed by pressing the SAVED DATA button at any time. When the analysis is finished, the user can save the results in a file by using SAVE TO FILE button. Using this button, the results will be saved in a file with ASCII format. It should be mentioned that the program sorts all the results in ascending order in time.

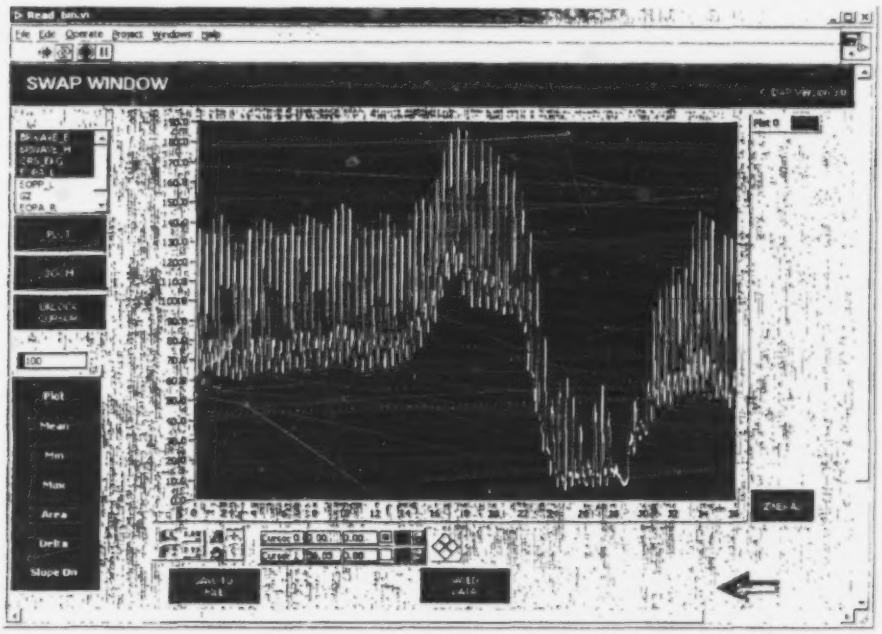


Figure 19. Expanded SWAP window

To return to the TASK MANAGER window just click on the BACK arrow.

8.2 PLAYBACK

Another feature in the TASK MANAGER window is the PLAYBACK feature. This feature replays the collected data and there is no analysis associated with this feature. Figure 20. shows the PLAYBACK window. To select a data file, hold Shift key and click the required data files. In general, maximum of five data channels can be displayed at the same time. The delay in plotting the data can be changed using the delay knob. To set the delay, click on the knob, hold the mouse key and rotate the knob to the required position. For fastest playback, set the knob

to zero. As it was mentioned before, this window is just for simulating collected data during an experiment. It can be used for visual inspection and presentation of the recorded data.

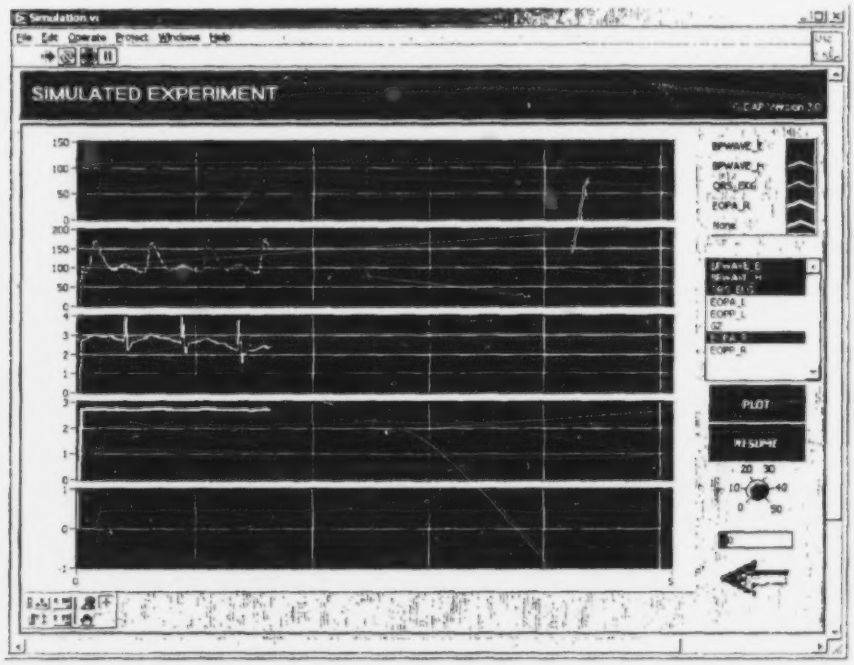


Figure 20. Play Back window

8.3 LabVIEW Features (Signal Processing and Statistical Analysis)

When the LABVIEW FEATURES button is pressed, a window shown in Figure 21 is presented.

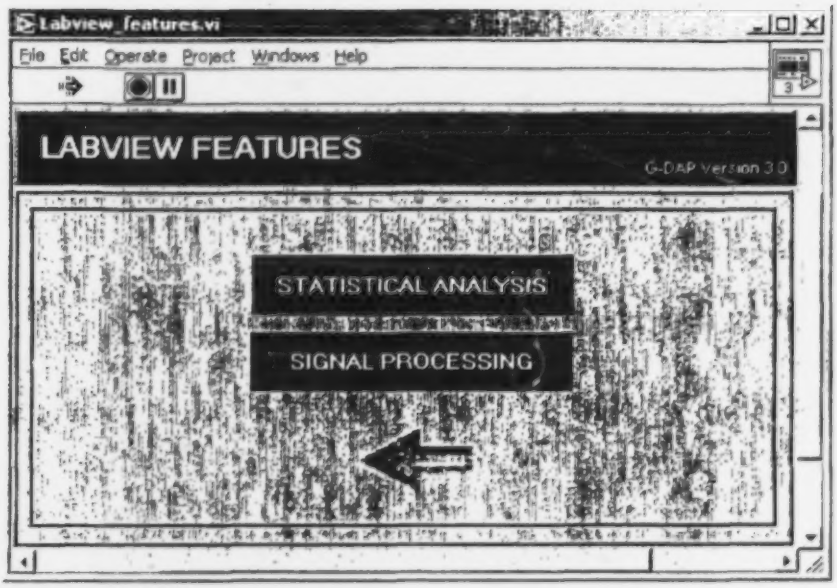


Figure 21. Labview Features window

- SIGNAL PROCESSING

The SIGNAL PROCESSING feature provides a set of analysis and signal processing functions available in LabVIEW software. It should be mentioned that the user could use this tool just for single channel ASCII file format. Figure 22 shows the ANALYSIS window. In general, the user can apply any type of filter or window to a selected signal. Any required signal or data can be selected in the same way as discussed in other windows (SWAP, PLAYBACK), that is, holding the Shift key and clicking the required data files. When the data is selected and the parameters are all set, press the PLOT button to perform the analysis. The result will be displayed in the chart. Use the RESET button to start with another setting. The PLOT button can be used for printing the result[4]. To perform further

[4] The user can print any of the windows for documentation or report just by clicking on the desired window (activate the window). Then hold the SHIFT and Alt keys and press Print Screen key. The picture will be copied into the clipboard. Next, it can be pasted into any application by using *Paste* command.

analysis such as FFT, Correlation, etc., first select the data file and then press the DSP button. Figure 23 shows the DSP window. In general, FFT, power spectrum, and correlation analysis are the features of this window.

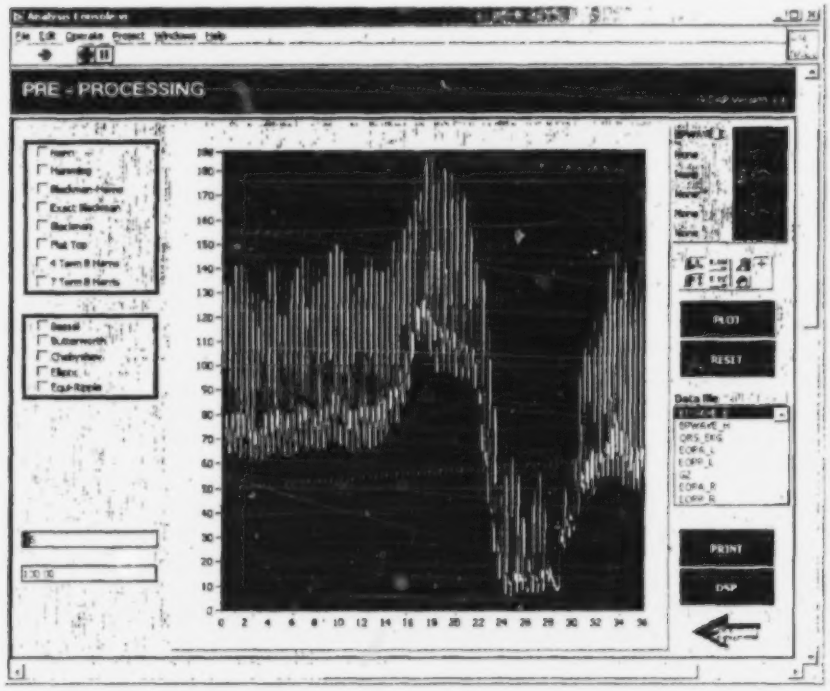


Figure 22. Analysis window

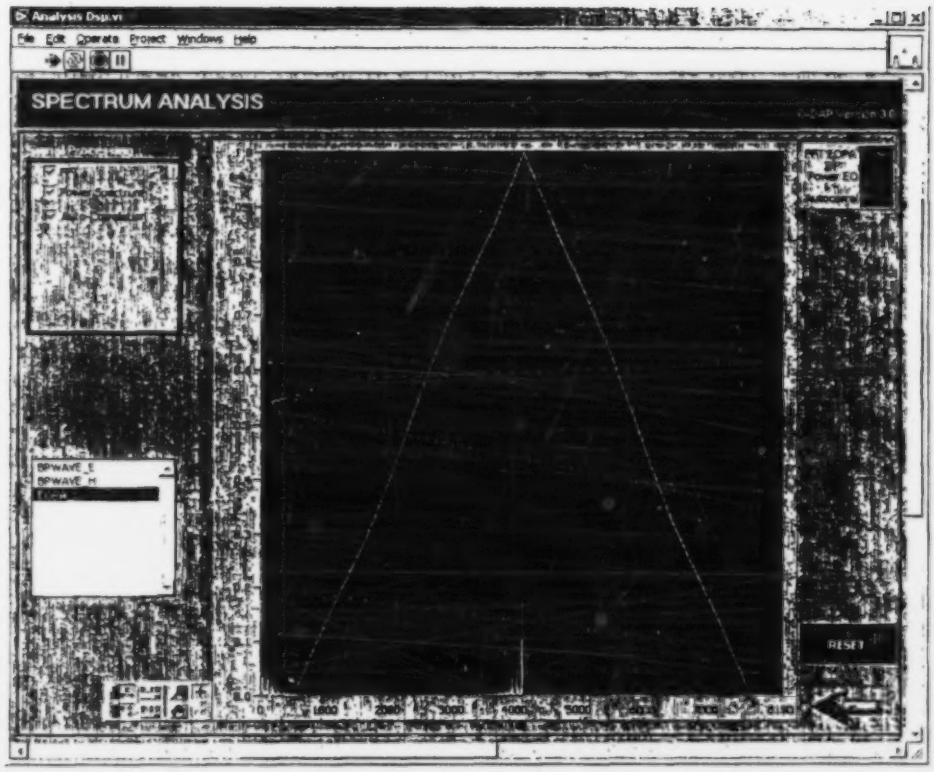


Figure 23. Digital signal processing window

- STATISTICAL ANALYSIS

The data files to be processed can be chosen from the data file listbox. If multiple data files are required, hold down the shift button on the keyboard and click on the desired files in the listbox simultaneously. Click on the desired function to be performed and then press the CALCULATE button to start the computation. The statistical result performed on the chosen data files will be shown on the Result indicator on the bottom of the window. The waveform of the data is also plotted on the graph. The STATISTICAL ANALYSIS window is shown in Figure 24.

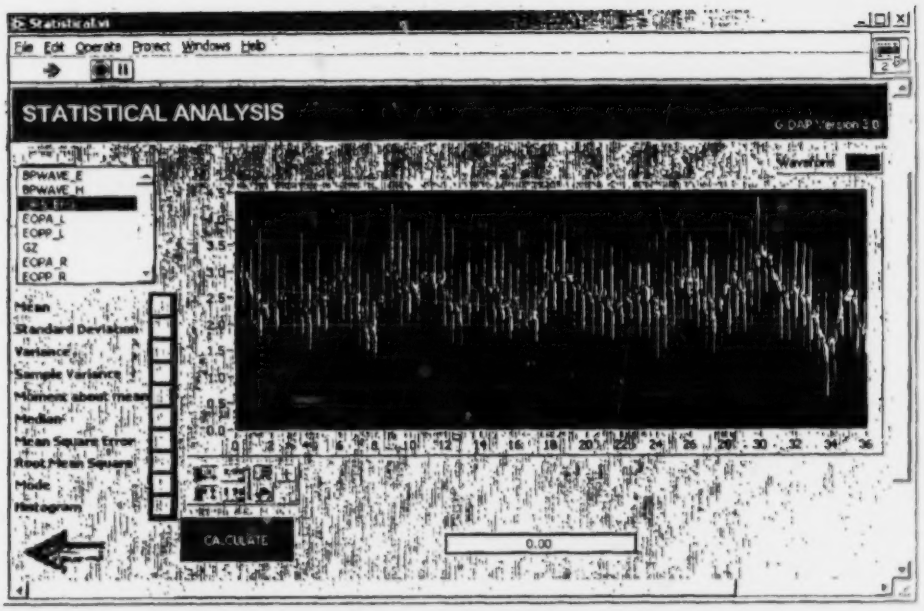


Figure 24. Statistical analysis window

8.4 CARDIAC INDEX, BLOOD FLOW, AND OPACITY OPTIONS

There were two options in TASK MANAGER window that were not implemented in G-DAP version 1.0, the 'CARDIAC INDEX & BLOOD FLOW' and 'OTHER' windows. The former one was implemented in version 2.0 of the G-DAP and is outlined in Chapter 11 of this report. The option dubbed 'OTHER' was replaced with OPACITY computation that was implemented in the latest 3RD version of G-DAP package, as outlined in Chapter 12 of this report.

8.5 G-DAP (THE ACCELERATION /GZ/ DATA ANALYSIS) OPTION

Using G-DAP option/button in the Task Manager, the user can implement user defined acceleration physiological data analyses. The flexibility of the calculation makes this feature interesting, but complicated for new users. Therefore, for new users there is a need to become familiar with the convention for analysis in this section. It is suggested to try some examples before using this feature for data

analysis. To help users understand all the features in the G-DAP window, this section discusses G-DAP option in detail.

8.5.1 Blood Pressure and ECG Calculation

By clicking the G-DAP button in TASK MANAGER window, the analysis starts by calculating the Systolic, Diastolic, and RR interval. Figure 25 shows the 'BP & ECG' window for calculating blood pressures and ECG peaks. Users need to press the ECG button first to open another window (see Figure 26 that displays the whole ECG signal. Using this window, the user needs to select a portion of ECG data that should be at least 10 seconds long and clean (no large distortion or noise). This portion of the data will be used to identify all the peaks of the ECG signal and calculation of RR intervals. Users can choose any part of the ECG signal by defining a 'selection window' on the required portion. Users can use the cursor or the plot utilities located on the lower right corner of the plotting window to define a 'selection window'.

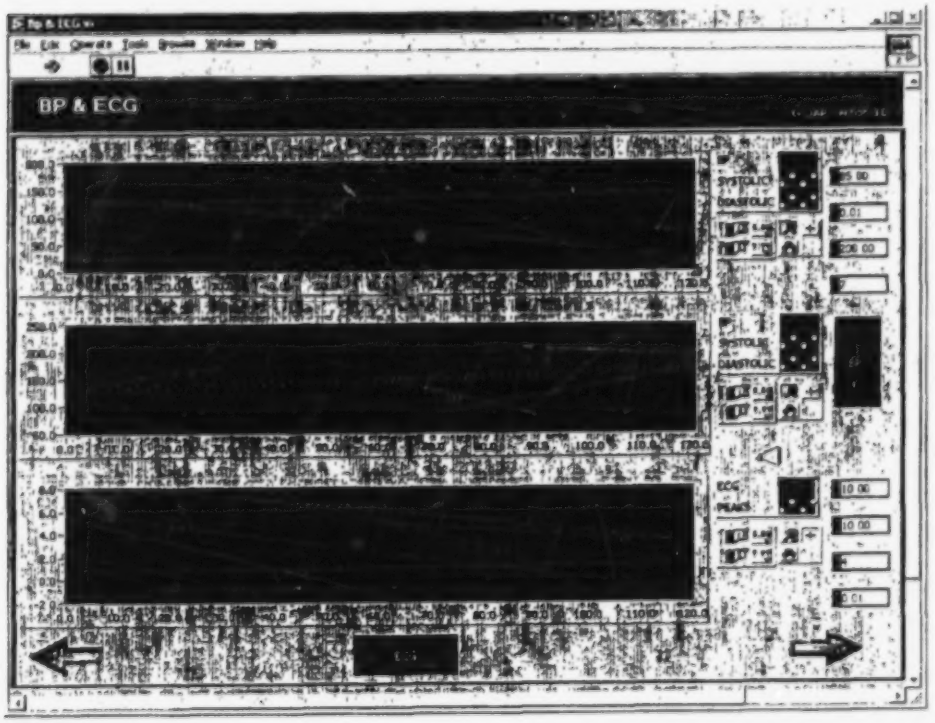


Figure 25. Blood pressure & ECG window

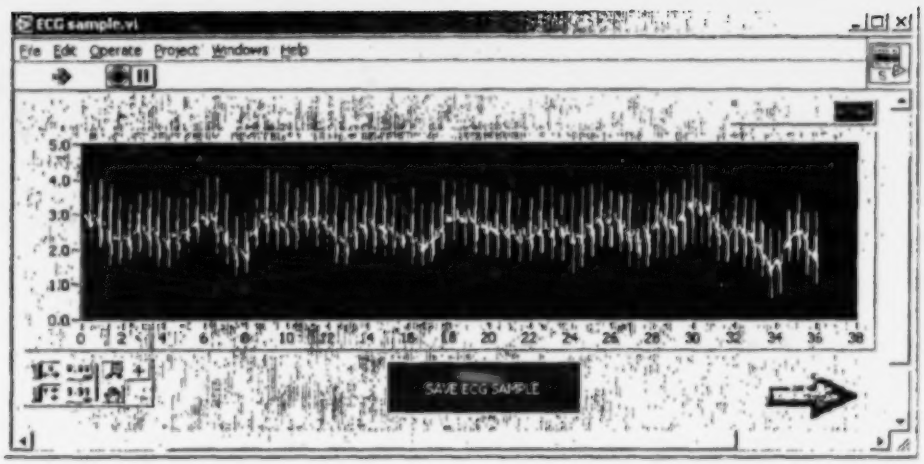


Figure 26. BP & ECG calculation window

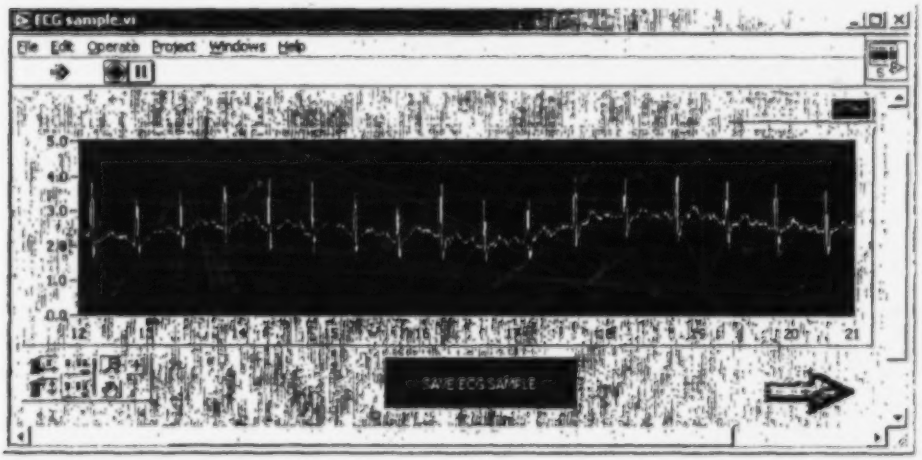


Figure 27. ECG sample window

By pressing the arrow 'NEXT' in ECG Sample window, it will return to the window 'BP & ECG'. All the peaks of ECG signal should be displayed by small yellow dots. The toggle switch let the user chooses between calculating systolic and diastolic pressures of opacity and blood pressure pulses. Press BP button to calculate the blood pressures (systolic and diastolic pressures). The systolic and diastolic pressures are also displayed by small dots with different colors (Figure

28). The user should inspect the peaks to ensure they have been selected correctly. Click on NEXT arrow when the calculation is finished to switch to the acceleration profiles window.

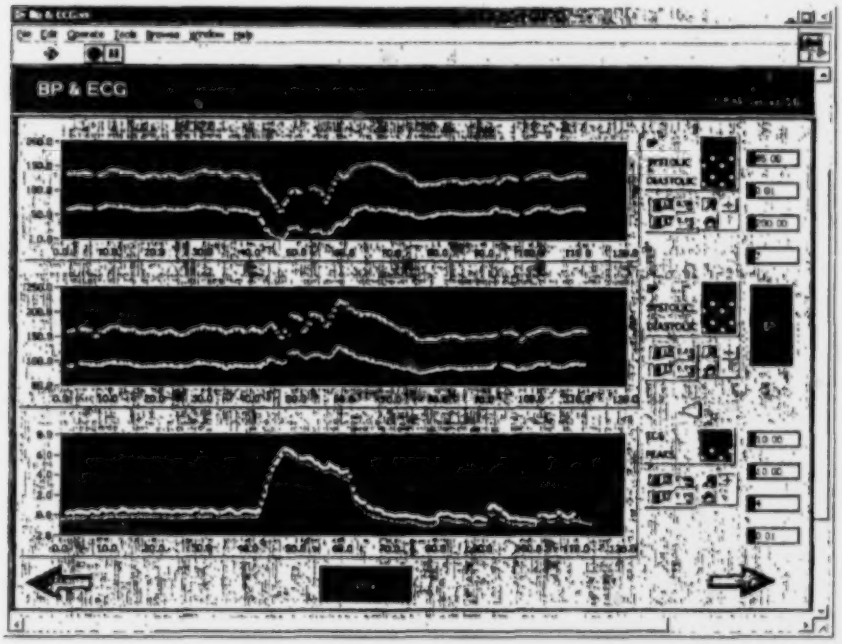


Figure 28. Calculated Systolic and diastolic pressures, and R-R interval.

By toggling the switch to the OPP position, the user can calculate opacity systolic and diastolic pressures by pressing the OPP button. Figure 29 shows the calculated opacity pulses values.

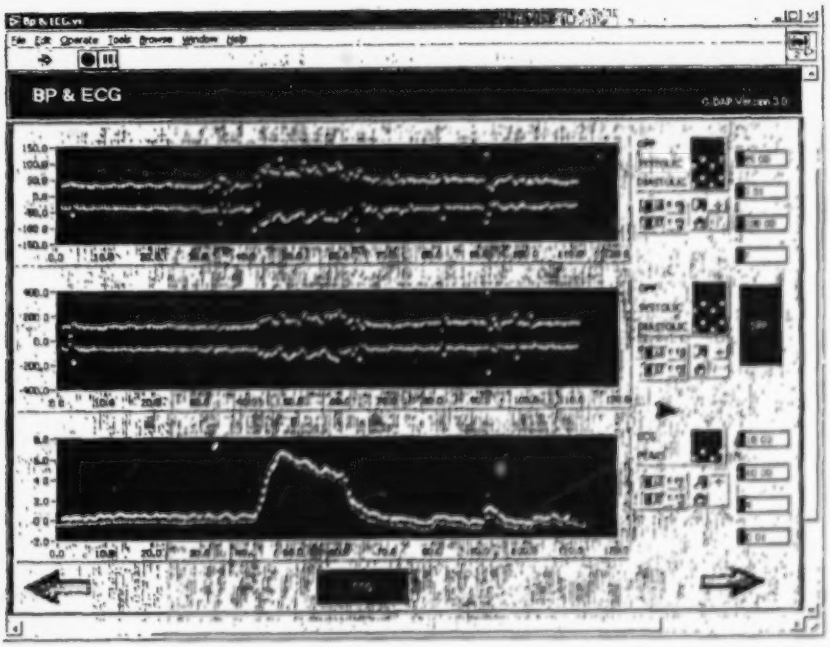


Figure 29. Systolic and diastolic pressure of opacity pulses

8.5.2 ACCELERATION PROFILE

Figure 30 shows the acceleration profiles and signal selection window. The user can choose the type of acceleration profile that best matches the experiment and then select the required signals through the analysis. These six acceleration profiles can be defined as follow:

- Push to Pull Gz: rest, negative Gz, then positive Gz.
- DRDC-TORONTO Centrifuge: rest, up to baseline Gz, then positive Gz.
- IFR Profiles: rest, bank aircraft, push –Gz, pull +Gz.
- Tilt-Table Profile: head-up tilt, head-down tilt, head-up tilt.

By selecting the acceleration profile the reference points (p1 to p7) in the Gz profile will be discussed in detail in the next section. In the Signal Selection

window, by checking the boxes 'G', 'BP', 'OPA', 'ECG' and 'HR', all boxes for sub variables will be set automatically. If there is no need for all the signal components, just click the desired ones and remove the checks in the master boxes. Only the signals that are checked will be processed in the following windows to calculate their indices.

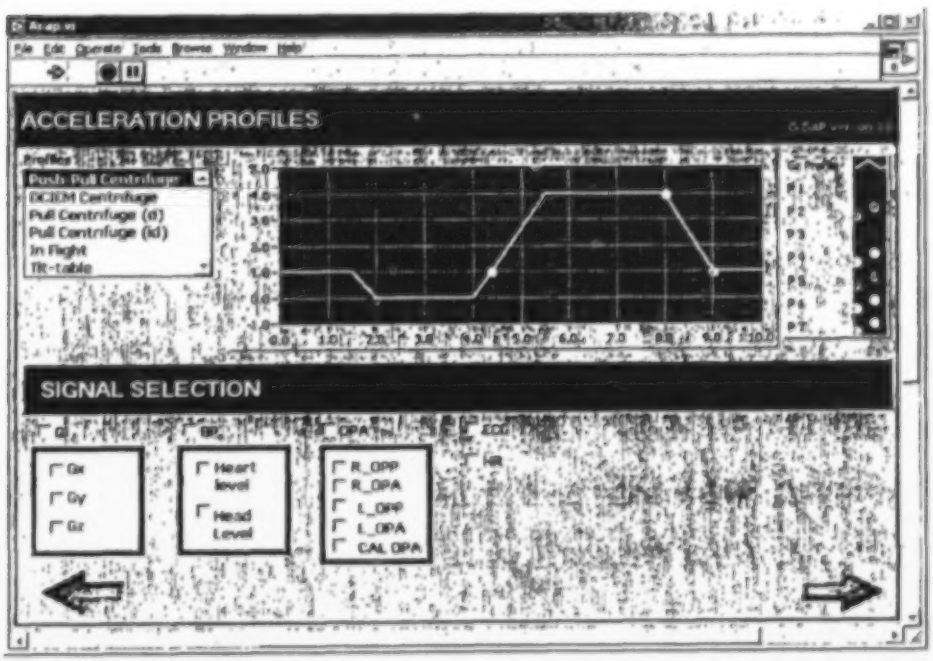


Figure 30. Acceleration profile

Figure 31 shows a set of selected signals for further analysis. After selecting the required signals, click NEXT arrow to open Gz reference points and modification window. Figure 32 shows the G-DAP REFERENCE PT & MODIFICATION window.

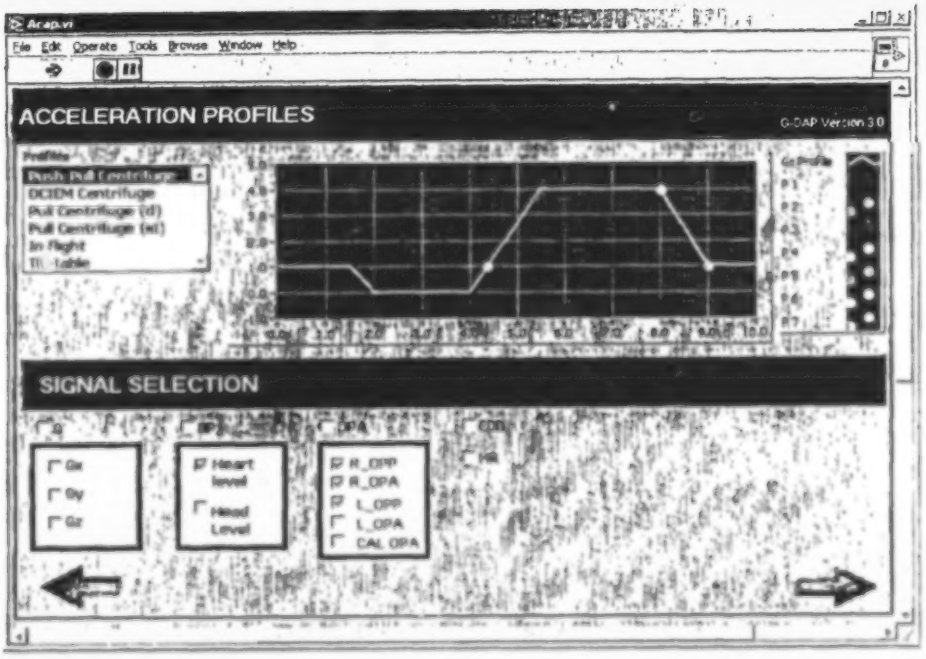


Figure 31. Selected signal for analysis

8.5.3 G-DAP Reference Points & Modification

Using this window (Figure 32) the G-DAP calculates all the predefined reference points used in subsequent analyses. To get more information about the definition for reference points just click on the HELP button. Click on the list box showing 'Gz Start', 'Gz Plateau', and 'Gz End' to calculate Gz reference points in the starting, plateau, and ending sections of the profiles. To calculate the reference points just click on CALCULATE button. The calculated points can be saved and loaded for future analysis.

After calculation, the user can examine the locations of the reference points. Figure 33 shows results for the calculated points. The user can change their positions by using DELETE and INSERT buttons. To delete a point just click on the blue cross pointer and move it to the desired point, then click the DELETE POINT button. To insert a point, first move the cursor to the desired position and then click INSERT POINT button. The SAVE button produces a *.gzref file and saves these reference points to a file for the loaded acceleration profile. This file

can be LOAD later for further analysis. When it is done click on NEXT arrow to go to the calculation configuration window.

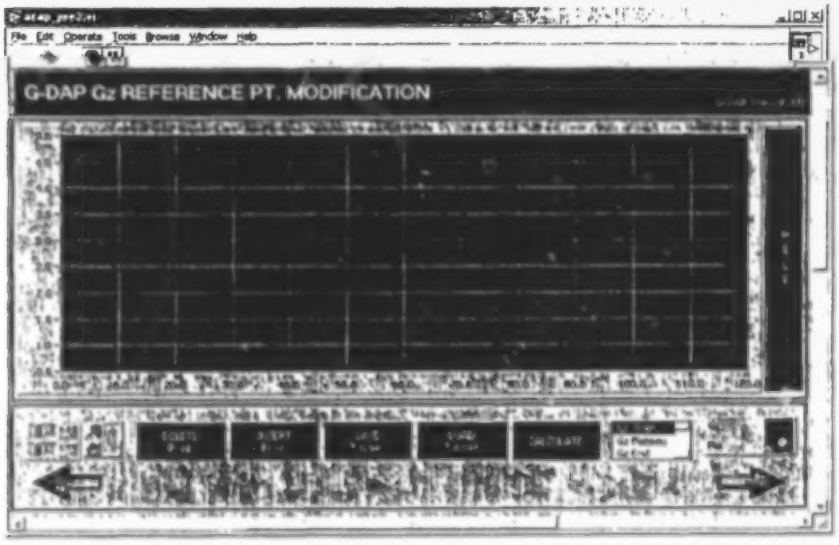


Figure 32. Acceleration profile setup window

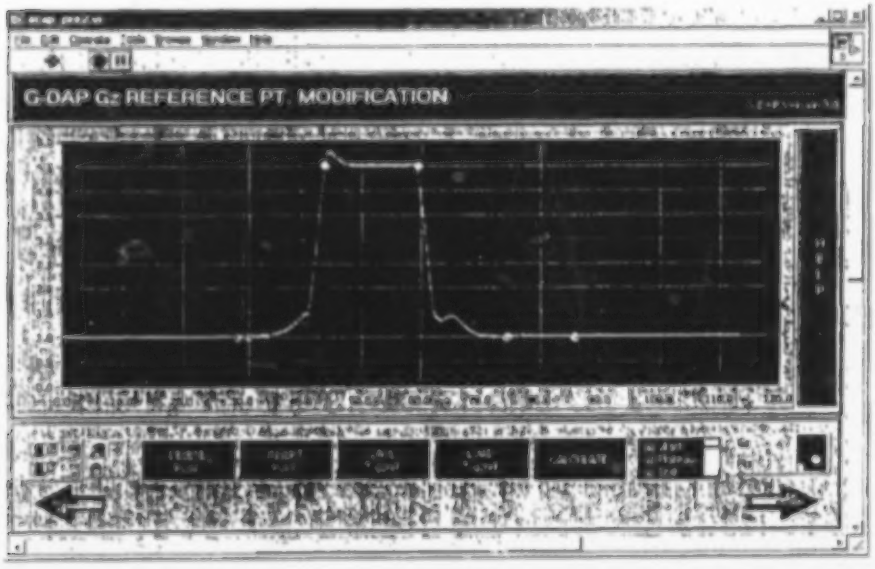


Figure 33. Calculated Gz reference points (P1 - P7)

In general twelve reference points are used in G-DAP for calculating the indices. Using HELP button a help window consists of definitions for P8 to P12 will be opened (Figure 34).

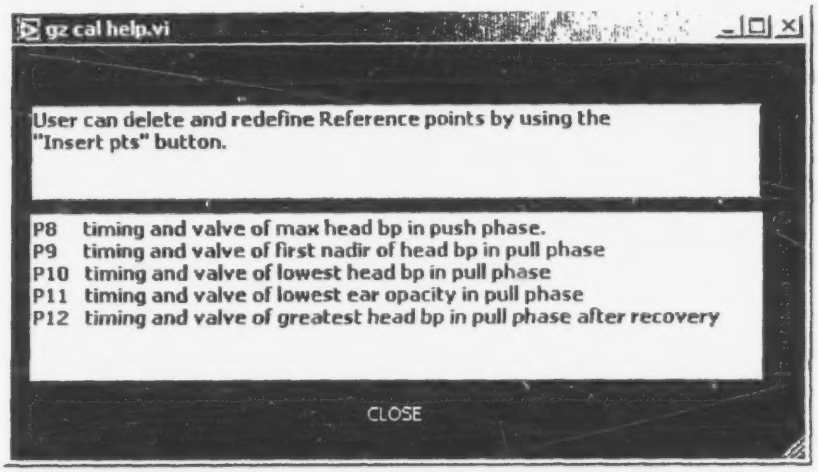

gz cal help.vi
User can delete and redefine Reference points by using the "Insert pts" button.
P8 timing and valve of max head bp in push phase.
P9 timing and valve of first nadir of head bp in pull phase
P10 timing and valve of lowest head bp in pull phase
P11 timing and valve of lowest ear opacity in pull phase
P12 timing and valve of greatest head bp in pull phase after recovery
CLOSE

Figure 34. Gz reference points definition help window

8.5.4 Calculation Configuration (Calculations of Physiological Indices)

Calculation of physiological indices are categorized into two modes: 'instant' and 'scope' modes. In 'instant' mode, values on a specific time instance of interest will be calculated by interpolation between two most adjacent points around the instance, while in a 'scope' mode, the values that are defined over a time period (such as average, maximum, minimum) will be calculated. To perform required calculations, a user needs to set up all the values in a parametric matrix in the window 'CALCULATION CONFIGURATION' (Figure 35). Each line of the matrix has five parameters that define a required calculation. In this window only eight rows are visible. If there is a need for more rows just click on the right upper corner button (1-8) and change the row numbers. In general eight rows at a time could be shown on the screen. Also, the left upper corner button shows the page number of configuration window. The following sections describe how to set up these parameters.

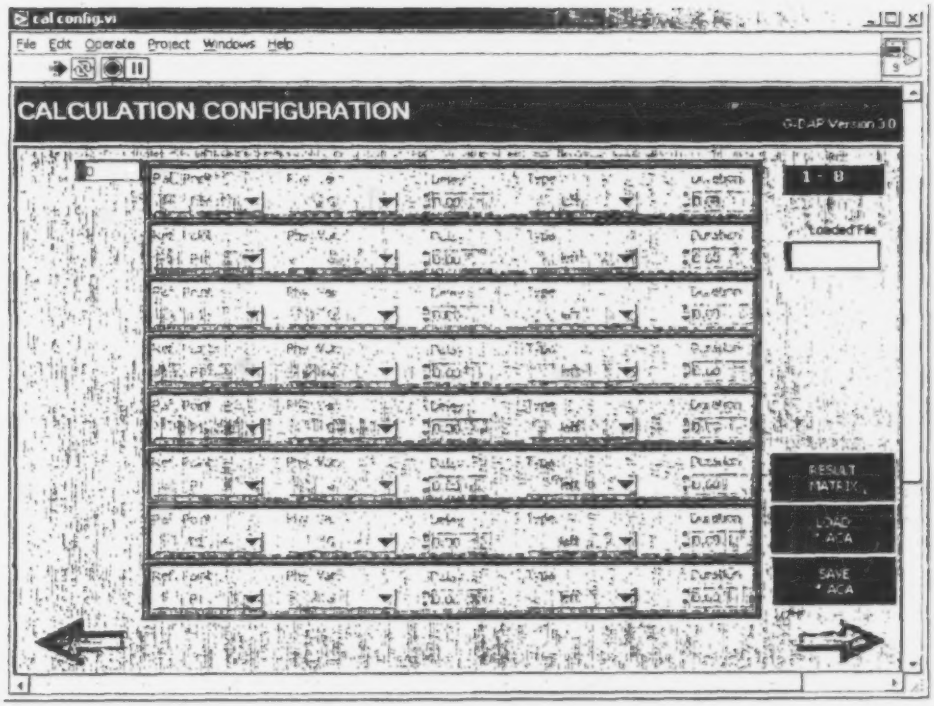


Figure 35. Calculation configuration window

By using LOAD button the user can load the previous saved configuration file (*.aca) (Figure 36). It is recommended to save all the calculation configuration files (*.aca) in Calconfig subdirectory. It helps the user to organize the files properly.

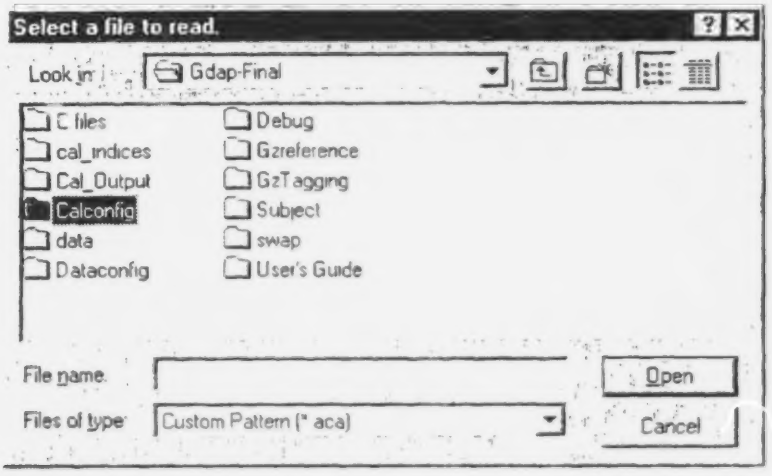


Figure 36. Loading configuration file

Figure 37 shows a loaded configuration file. For a new analysis, the user needs to set the configuration file and save it for future analysis.

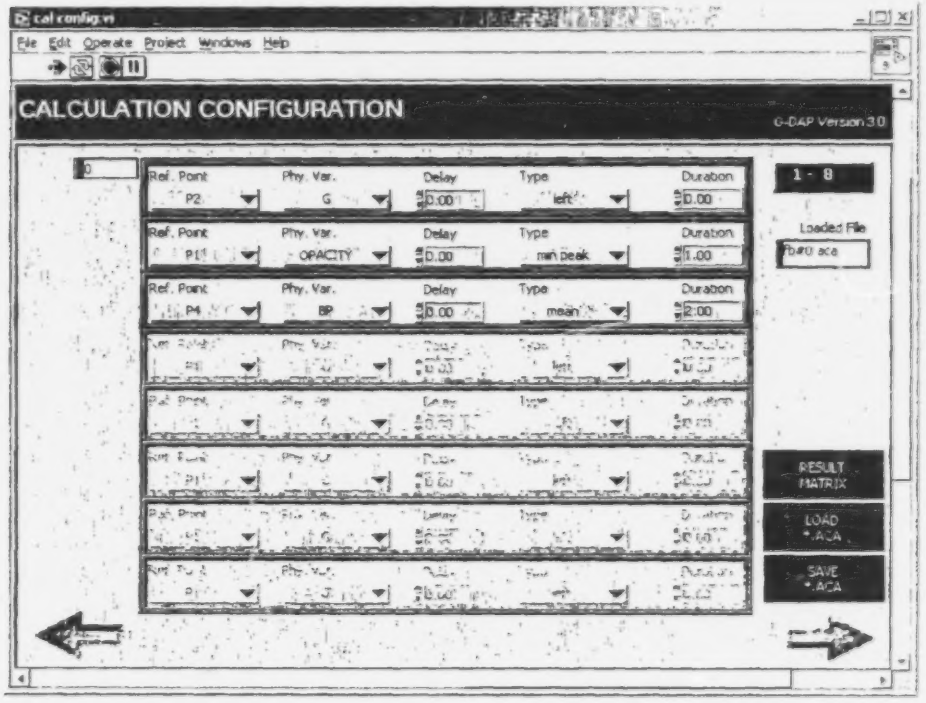


Figure 37. Calculation configuration setup window

When the configuration is done the user could check the calculation array by pressing the RESULT MATRIX button. Figure 38 shows the calculation array matrix. This matrix shows how many calculations will be done for the prepared configuration. For example, for three-rows configuration there is a need for four calculations. This matrix passes some codes to the low-level routines for calculating the requested indices.

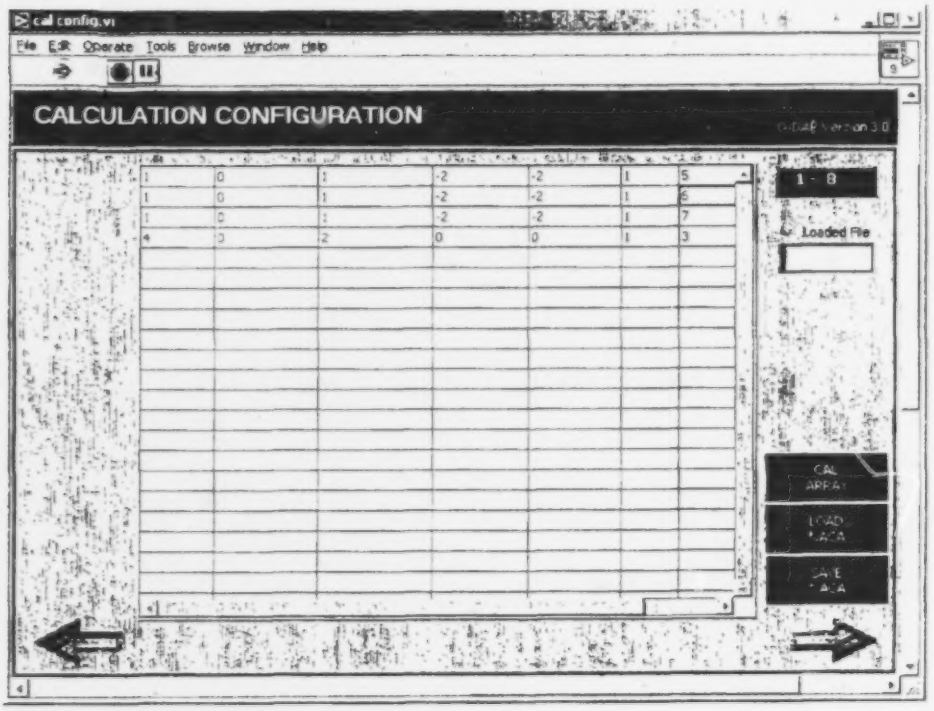


Figure 38. Calculation configuration matrix

9 REFERENCE POINTS DEFINITIONS

In both calculation modes, all the timings (time instances or periods) are defined with respect to the reference points. The first column *'Ref. Points'* in the 'CALCULATION CONFIGURATION' window (Figure 38) lets a user select proper reference points. Click the button ***P1*** to display a list of all reference points numbered from p1 to p12. All these reference points are based on Gz profiles and certain predefined physiological events. First seven reference points

only depend on Gz profile and are shown in Figure 39. It is noted that there is no reference point 2, 3 or 4 for a 'Pull' profile of acceleration.

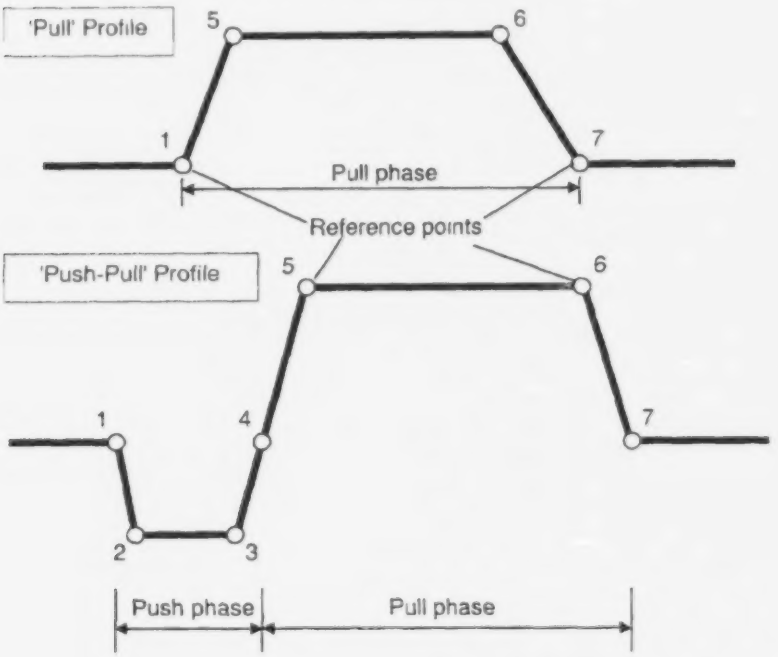


Figure 39. Gz defined reference points

The other five reference points are related to certain customer defined physiological indices and explained as follows:

8. Greatest head-level blood pressure in push phase.

9. First nadir of head-level blood pressure in pull phase (may be same as #10).

10. Lowest head-level blood pressure in pull phase (may be same as #9).

11. Lowest amplitude of ear opacity in pull phase.

12. Greatest head-level blood pressure in pull phase after recovery.

9.1 PHYSIOLOGICAL VARIABLES

The second column '*Phy. Var*' lets user to choose the physiological and acceleration variables for calculation of their indices. Click the G button to display a list of the following physiological and Gz variables:

G --- it includes those G force signals that are chosen in a previous window 'G-DAP ACCELERATION PROFILES', such as *Gx*, *Gy* and *Gz*.

BP -- it includes those blood pressure signals that are chosen in a previous window ' G-DAP ACCELERATION PROFILES ', such as head-level and heart-level blood pressures: *BP_HEAD* and *BP_HRT*.

OPA -- it includes those ear opacity signals that are chosen in a previous window ' ACAP ACCELERATION PROFILES ', such as left and right ear opacity signals: *EOPA_L* , *EOPA_R*, and ear opacity pulse signals.

ECG -- it includes ECG signal that is selected in a previous window ' G-DAP ACCELERATION PROFILES '.

9.2 CALCULATION DELAY

The third column '*Delay*' lets users set calculation timings with respect to the reference points. The values of the variables defined in '*Phy. Var*' will be retrieved or calculated at the calculation timings. User can define the amount of 'delay' by inputting a proper number in a dialog window. The unit is second. If the number is negative, for example, -5, the calculation timing is 5 seconds before the reference point. If the calculation is in 'scope' mode, this number defines the starting point of the time period. For example, if the number is 5, the starting point of the period is 5 seconds after the reference point. The length of the period will be defined in the column '*Duration*'.

9.3 CALCULATION DURATION

The column '*Duration*' sets the length of calculation time period. User can define the length by inputting a proper number in a dialog window. The unit is seconds. This number also determines which calculation mode is to be used. If a user wants an 'instant' mode, this number must be set to zero. A nonzero number is only used for 'scope' mode calculation.

9.4 CALCULATION TYPE

The column '*Type*' defines different calculation types. Click on button to display a list of eight calculation types. The first three types are for 'instant' mode: left, instantaneous and right. The last five types are for 'scope' mode: min peak, min, mean, max, max peak. The descriptions of these types are as follows.

Instant Mode:

left --- if the value of a variable is not defined at the precise calculation timing, the program will select the value at the instance that is nearest to the calculation timing on the left side (just *before* the calculation timing) (refer to Figure 40). Elapsed time moves from left to right.

right --- if the value of a variable is not defined at the precise calculation timing, the program will select the value at the instance that is nearest to the calculation timing on the right side (just *after* the calculation timing) (see Figure 40).

instantaneous --- if the value of a variable is defined at the calculation timing, the program will select the value at this instance. Otherwise, an interpolation point at the calculation timing between the 'left' and 'right' points that are defined in the above types *left* and *right* will be calculated (see Figure 40).

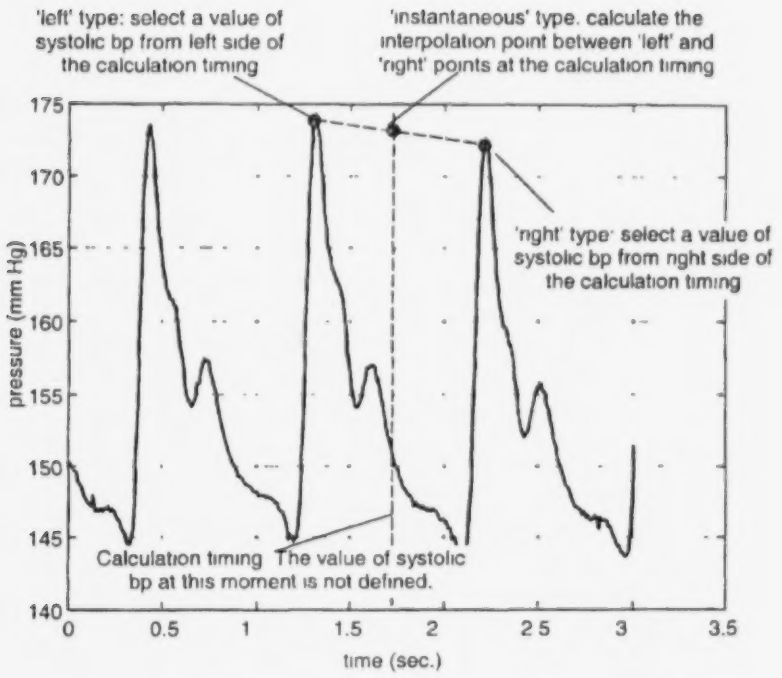


Figure 40. Instant mode calculation for blood pressure

Scope Mode:

min --- minimum value of a variable over a time period.

min peak --- minimum peak value of a variable over a time period.

mean --- mean value of a variable over a time period.

max --- maximum value of a variable over a time period.

max peak --- maximum peak value of a variable over a time period.

In the 'scope' mode, the user needs to define the starting point and length of the time period. The starting point is defined in '*Delay*' and length is defined in '*Duration*'. Figure 41 shows the examples of 'scope' mode calculations for ear opacity signal.

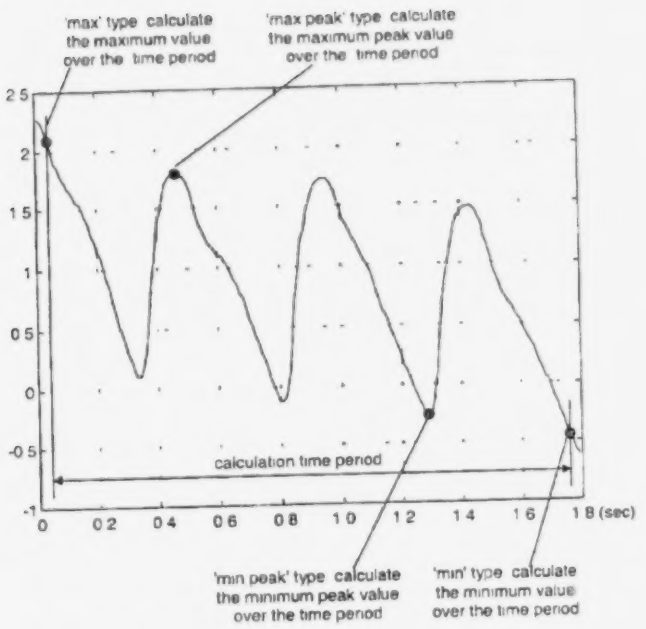


Figure 41. Scope mode calculation for ear opacity signal

10 EXAMPLES

Table 1 gives several examples to set up configuration parameters for different calculations.

Table 1. Examples of setting up configuration parameters

Calculation Specification	reference point	physiological signal	delay (sec)	Type	Duration (sec)
1) approx. 20 sec before push; mean in approx. 10 beats	p1	Gz, Sys. Opa, etc,	-20	Mean	10
2) just before push phase;1 beat	p1	Gz, Sys. Opa, etc,	0	Left	0

3) start on push phase (Gz<1);	p1	Gz, Sys. Opa, etc,	0	Right	0
4) end of push phase (Gz = 1);	p4	Gz, Sys. Opa, etc,	0	Instanta neous	0
5) greatest head BP in push;	p8	Gz, Sys. Opa, etc,	0	Instanta neous	0
6) BP at end of push phase; (1 beat to left);	p4	Gz, Sys. Opa, etc,	0	Left	0
7) start of pull phase (Gz>1)	p4	Gz, Sys. Opa, etc,	0	Right	0
8) end of pull phase	p7	Gz, Sys. Opa, etc,	0	instanta neous	0
9) first nadir of head BP in pull; 1 beat	p9	Gz, Sys. Opa, etc,	0	instanta neous	0
10) BP at t=5s in pull; 1 beat	p5	Gz, Sys. Opa, etc,	5	right	0
11) BP at t=10s in pull; 1 beat	p5	Gz, Sys. Opa, etc,	10	right	0
12) lowest head BP in pull; 1 beat	p10	Gz, Sys. Opa, etc,	0	instanta neous	0
13) lowest ear opacity in pull	p11	Gz, Sys. Opa, etc,	0	instanta neous	0
14) greatest head BP in pull after recovery	p12	Gz, Sys. Opa, etc,	0	instanta neous	0

11 G-DAP CALCULATION RESULTS

Calculation of physiological parameters defined in configuration file will be performed automatically by pressing the NEXT button in 'CALCULATION CONFIGURATION' window in Figure 42. Figure 43 shows the G_DAP CALCULATION RESULTS window.

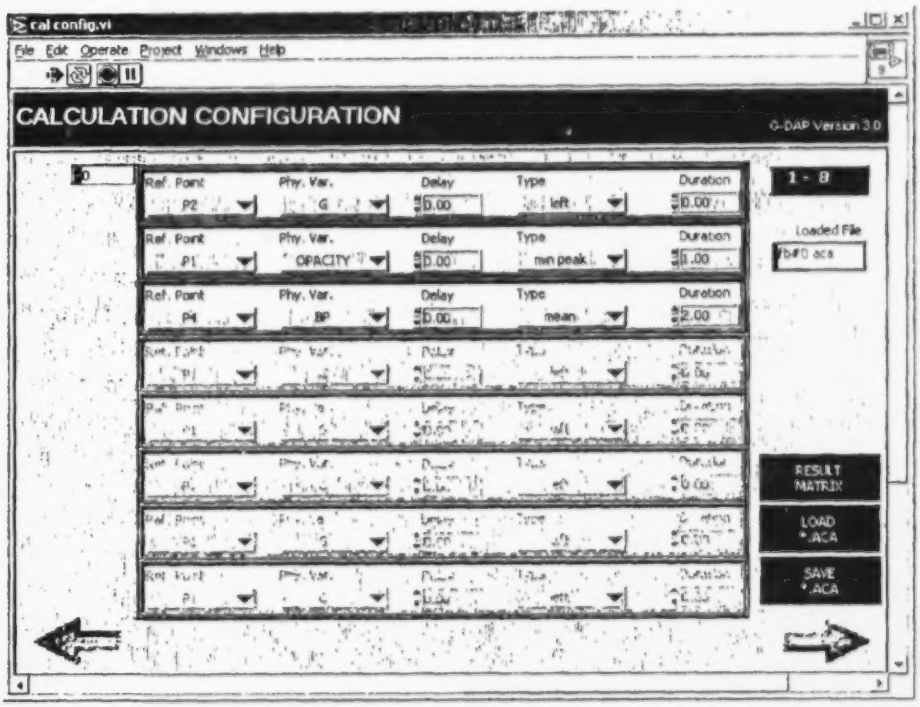


Figure 42. Calculation window

There are three plots in G-DAP CALCULATION RESULTS window. The top plot shows the Gz profile and the two other plots can be chosen by the user. To plot any signal listed in the box right to the plot, the user should first select the signal by right click of the mouse on the signal and then press PLOT button. For example, Figure 43 shows the blood pressure selection for plotting. It should be mentioned that the calculated value for the plotted signal will be appear in the plot (Figure 44). For this case, the value for the systolic and diastolic blood pressures at head level for P4 location is marked in the plot. Also, Figure 45 shows the ear opacity signal plot and the ear opacity calculated value. Figure 45 shows that the

systolic and diastolic pressures of opacity pulses at P1 is calculated. In general, the user could use the plot utility here to check the calculated points by G-DAP. Figure 46 shows the reference point on opacity amplitude signal.

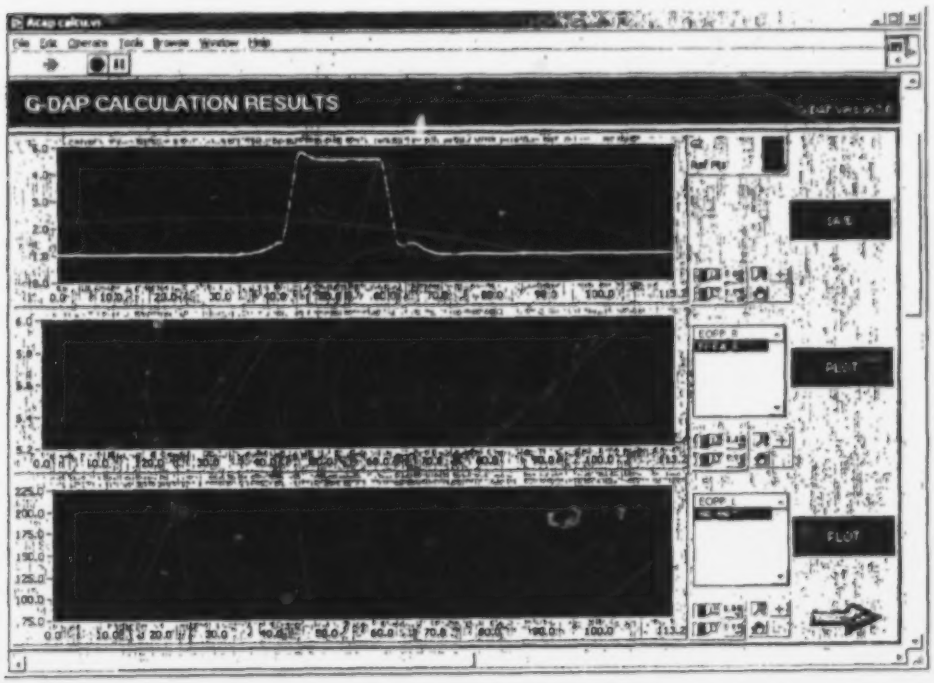


Figure 43. G-DAP calculation results

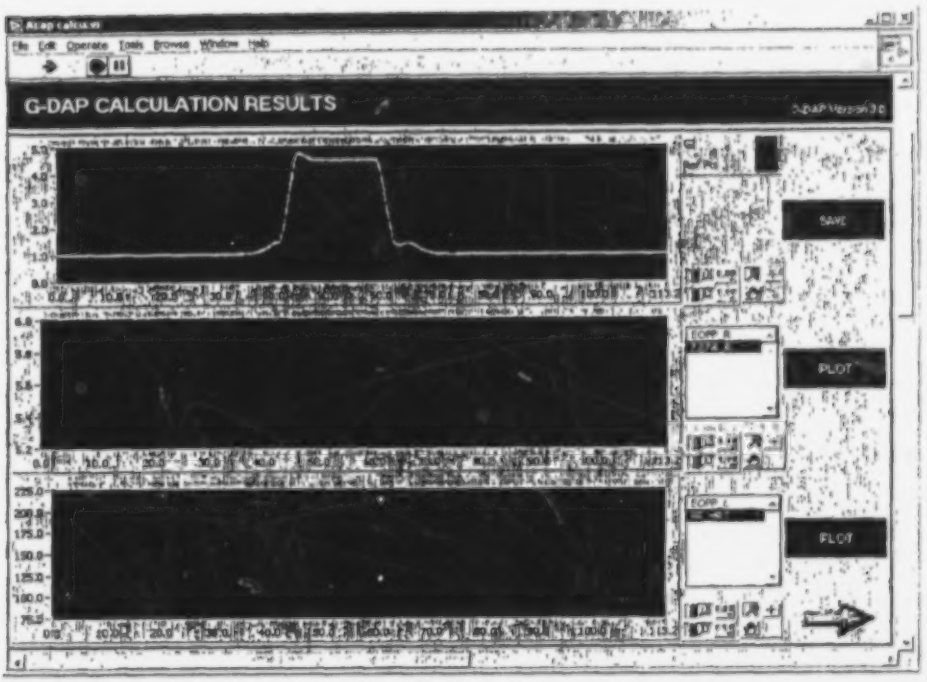


Figure 44. G-DAP calculation results "Blood Pressure"

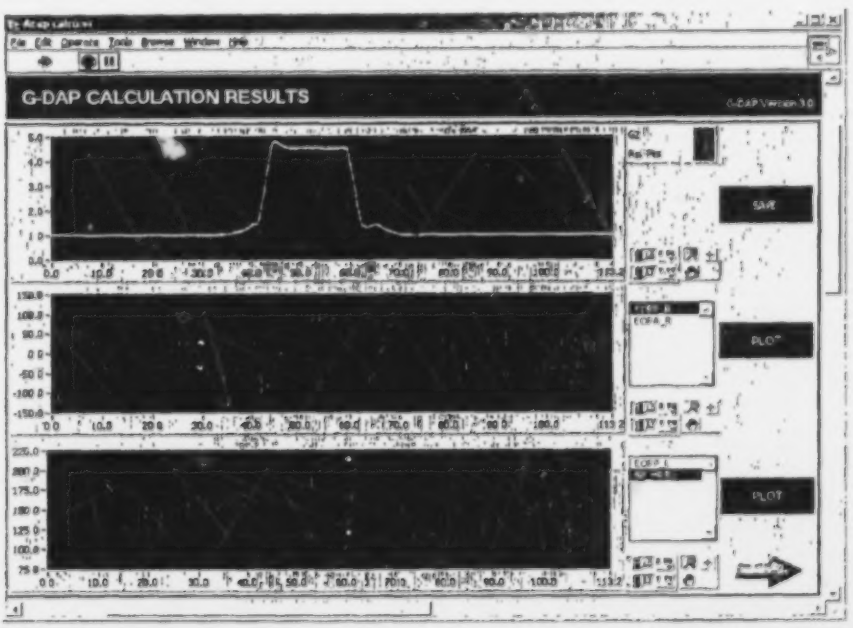


Figure 45. Systolic and diastolic pressures of opacity pulses at P1

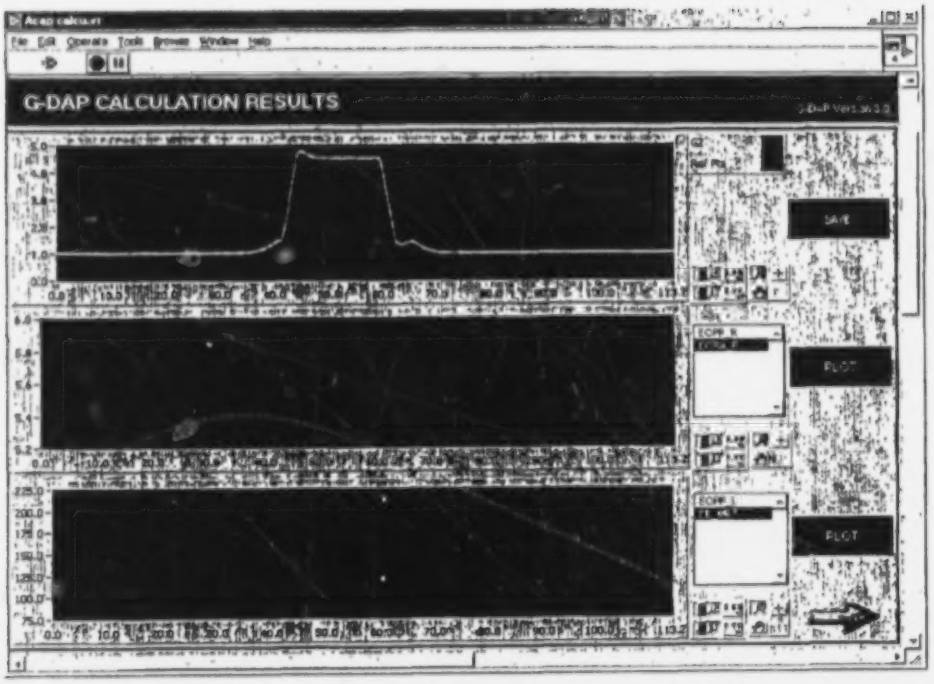


Figure 46. G-DAP calculation results (blood pressure & ear opacity)

When analyses are finished, to save the results just press SAVE button. The results will be saved in Microsoft Excel format (*.xls). Figure 47 shows the saving window.

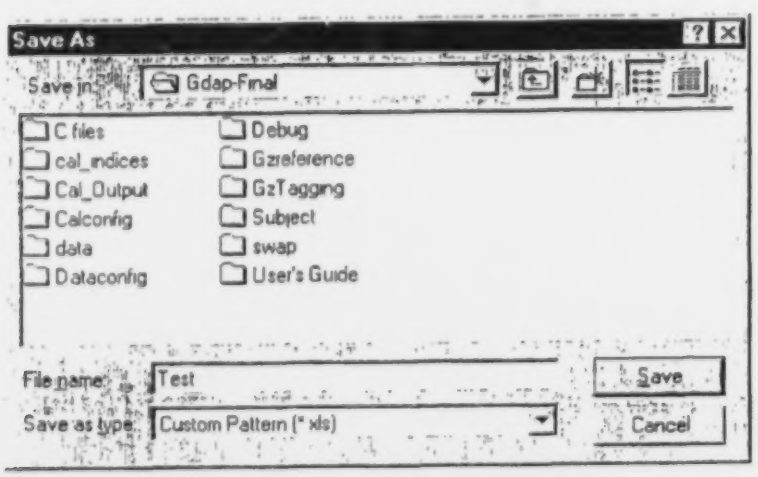


Figure 47. Saving calculation results window

Finally, Figure 48 shows the loaded output result in Microsoft Excel. The data filename, configuration filename, and the subject filename are the first three lines in output file followed by a definition for reference points P8-P12. The calculated values are in nine columns. The first column is the reference point (e.g. 1 means P1). The second and third columns are delay and duration, respectively. If the value is an instantaneous value the corresponding term will be in Cal1 column (fourth column). However for the 'Scope' mode the corresponding term will be in fifth column (Cal2). Column sixth is Gz profile type, and column seventh is the channel number. Finally, the calculated value together with its corresponding time are presented in the last two columns.

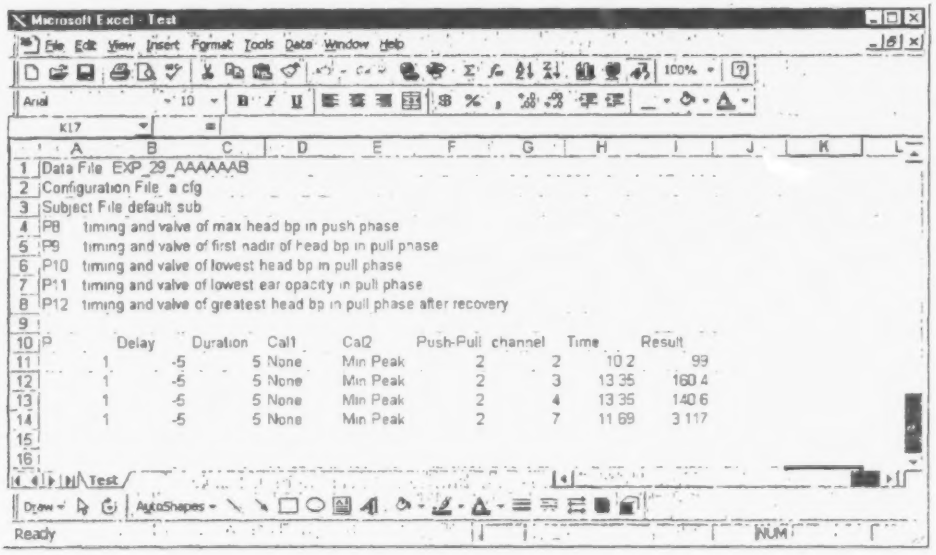

Microsoft Excel - Test
Data File EXP_29_AAAAAAB
Configuration File a.cfg
Subject File default.sub
P8 timing and valve of max head bp in push phase
P9 timing and valve of first nadir of head bp in pull phase
P10 timing and valve of lowest head bp in pull phase
P11 timing and valve of lowest ear opacity in pull phase
P12 timing and valve of greatest head bp in pull phase after recovery
P Delay Duration Cal1 Cal2 Push-Pull channel Time Result
1 -5 5 None Min Peak 2 2 10.2 99
1 -5 5 None Min Peak 2 3 13.35 160.4
1 -5 5 None Min Peak 2 4 13.35 140.6
1 -5 5 None Min Peak 2 7 11.69 3.117
Test
Ready
NUM

Figure 48. G-DAP output file (EXCEL format)

12 CARDIAC INDEX & BLOOD FLOW CALCULATION TOOLBOX

Another important feature of TASK MANAGER window is CARDIAC INDEX & BLOOD FLOW Toolbox. This toolbox has been implemented in G-DAP Version 2. Press the CARDIAC INDEX & BLOOD FLOW button in the TASK

MANAGER to open the CARDIAC INDEX & BLOOD FLOW calculation window as shown in Figure 49.

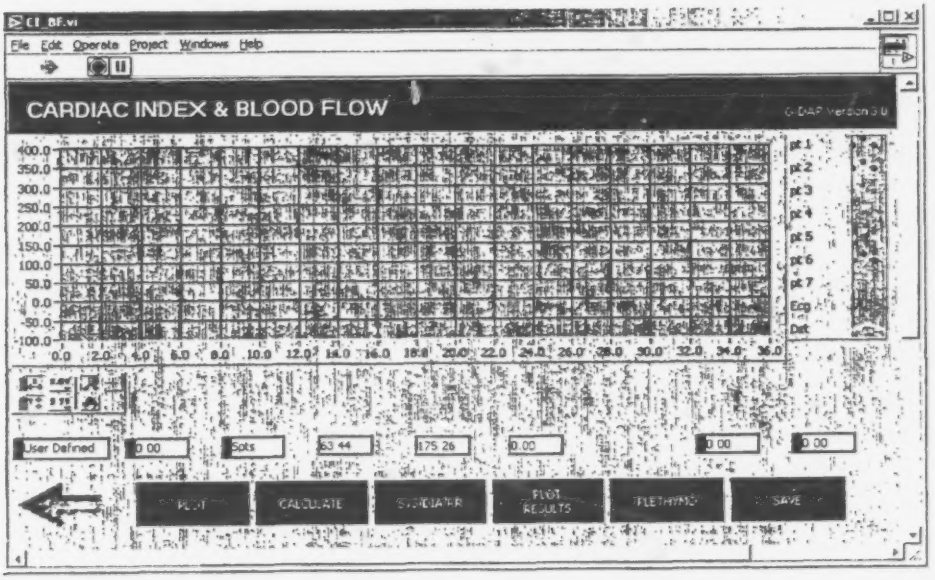


Figure 49. Cardiac Index & Blood Flow Calculation

The following controls are available in this window and the user can define or select the values for further analysis:

1. ***Zo definition***:

   - ***(User defined)*** – Zo is defined manually using the Zo control (See Figure 50).

   - ***(Automated)*** – Zo will be calculated based on the information in loaded data file, Zo control disappears.

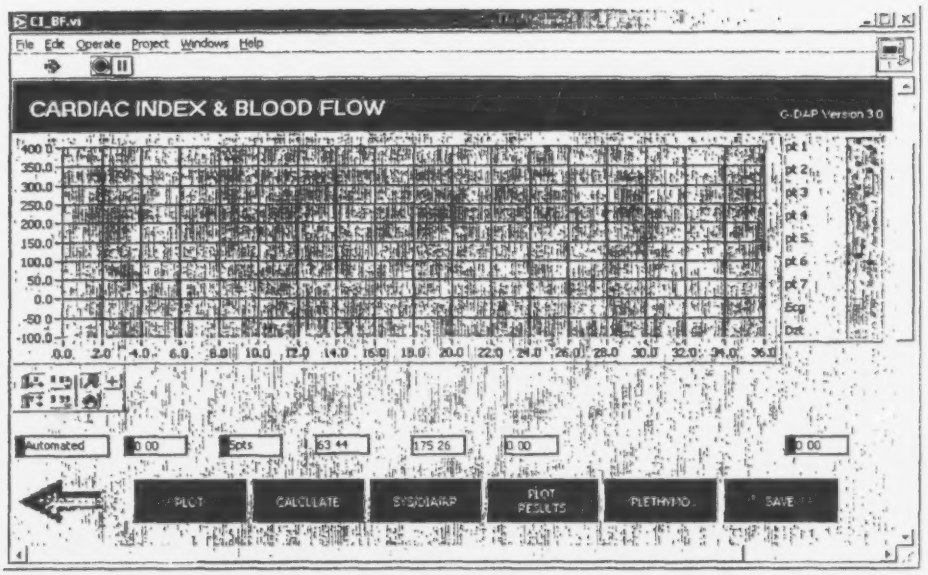


Figure 50. Definition Z0 window

2. ***Hct***: Used to calculate rho. This value will be used for cardiac output calculation.

3. ***Enum***: Calculation method for selecting the rise time in impedance signal. There are two choices:

   - ***Spts***- Using $t_X - t_S$
   - ***Bpts***- Using $t_X - t_B$

4. ***Weight***: The weight of subject (Kg)

5. ***Height***: The Height of subject (Cm)

6. ***rho***: $2.102 \times Hct + 30.098$

7. ***BSA***: $0.202 \times Height^{0.725} \times Weight^{0.425}$

8. ***Zo***: User defined Zo value. This control is only visible if Zo definition is chosen to be 'User'.

9. *L*: This value is used to calculate Stroke Volume (SV) of the Kubicek equation

Clicking the PLOT button plots the ECG and Dzt signals of the loaded data file as shown in Figure 51.

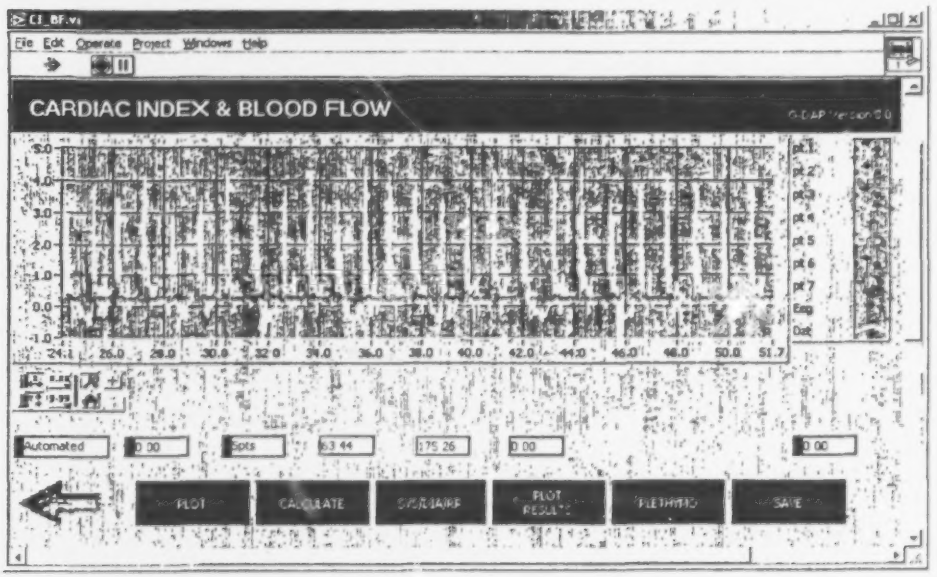


Figure 51. Plotted ECG & Dzt signals

Clicking the CALCULATE button will compute and plot the peaks and valleys of both the ECG and Dzt signals as shown in Figure 52.

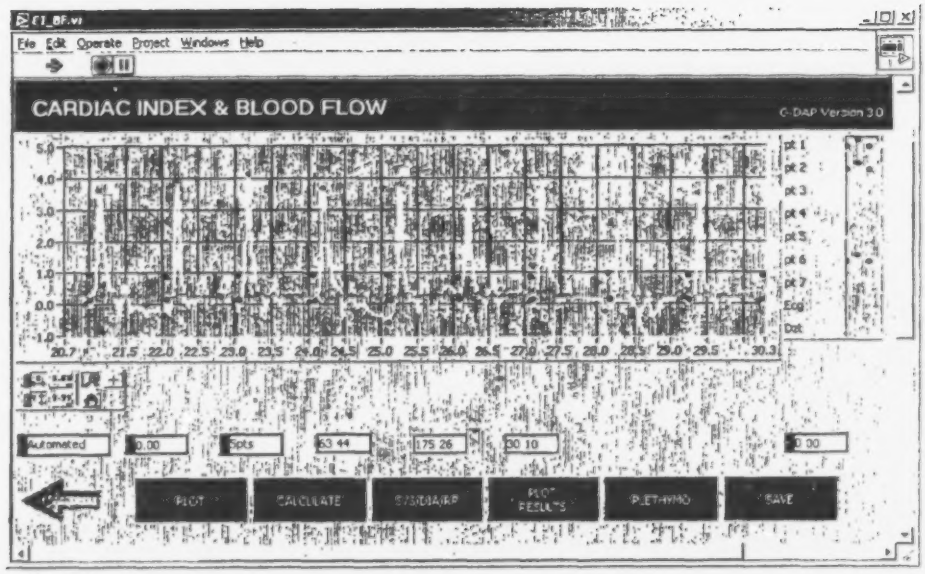


Figure 52. Calculated points for ECG & Dzt signals

The CALCULATE button also computes the following physiological parameters using two formulas, Sramok & Kubicek:

- Heath Index,
- Ejection Fraction
- Acceleration
- HR
- LVET
- SV
- SI
- CI
- CO

Please note that CALCULATE button should only be operated when all the variables needed by the physiological parameters defined above (variables such as Weight, Height, etc.) have been defined. Clicking the PLOT RESULTS button opens the window shown in Figure 53. This window plots the results generated by the CALCULATE button. To plot the results on the graph, choose the desired data from the data list-box on the top left-hand corner of the window and press the PLOT button. If multiple data sets are desired, hold down the shift button and then click on the data sets to be plotted simultaneously. The RESET button clears the graph.

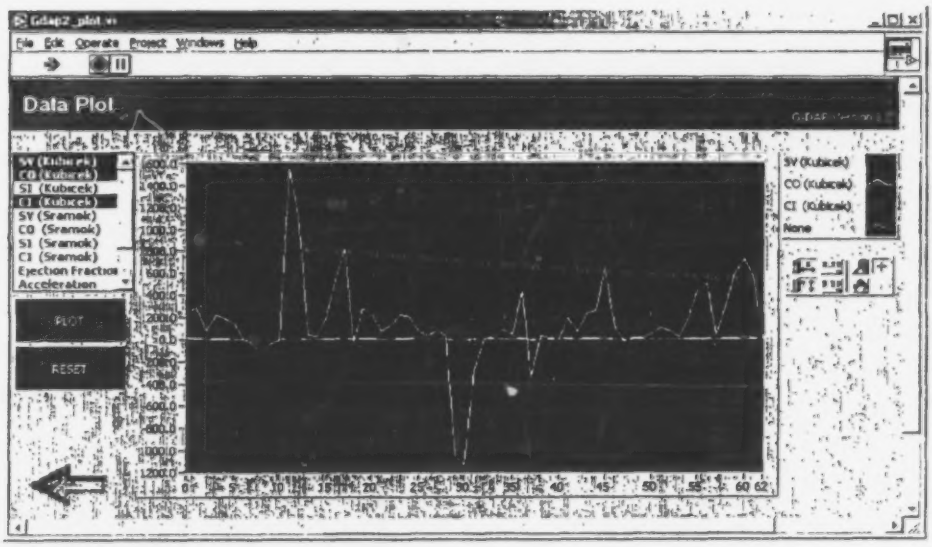
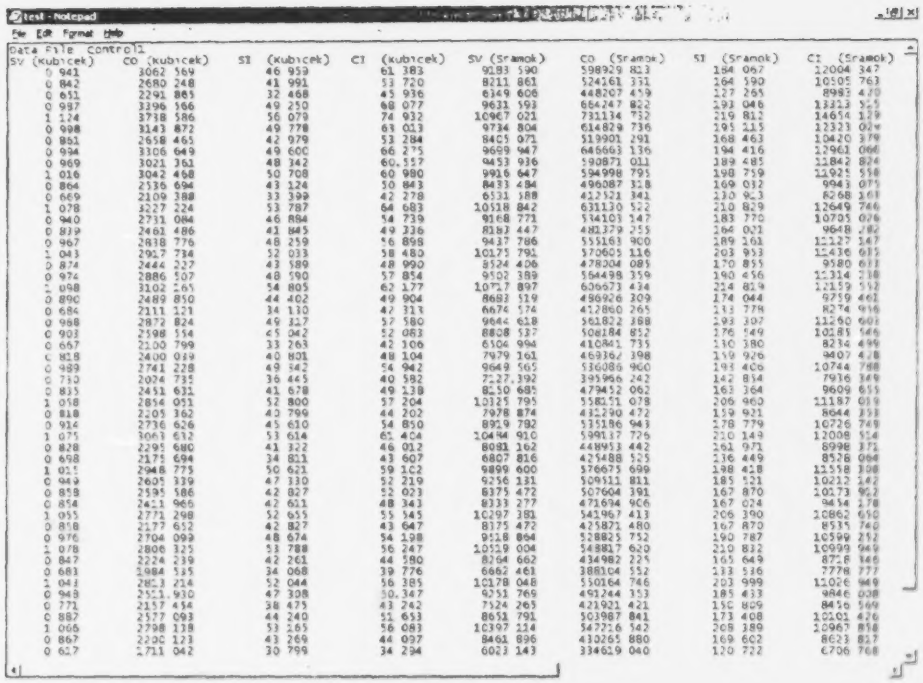


Figure 53. Calculated results window

Clicking on the SAVE button on the CARDIAC INDEX AND BLOOD FLOW window save the results generated by the CALCULATE button into a data file. The data is shown in Figure 54.



test - Notepad

File Edit Format Help

Data File control2

SV (kubicek)	CO (kubicek)	SI (kubicek)	CI (kubicek)	SV (Sramek)	CO (Sramek)	SI (Sramek)	CI (Sramek)
0 941	3062 569	46 959	61 383	9283 590	598929 823	184 067	12004 347
0 842	2680 248	41 991	53 720	8211 861	524161 331	164 590	10505 763
0 651	2291 865	32 468	45 936	6349 606	448207 459	127 265	8983 470
0 987	3396 166	49 250	68 077	9631 593	664247 822	193 046	13313 565
1 124	3738 586	56 079	74 932	10967 021	731134 752	219 812	14654 129
0 998	3143 872	49 778	63 013	9734 804	614829 736	195 215	12321 024
0 861	2658 465	42 979	53 284	8405 071	519901 291	168 463	10420 379
0 994	3106 649	49 600	66 275	9689 947	646663 136	194 416	12961 066
0 969	3021 361	48 342	60.557	9453 936	590871 011	189 485	11842 824
1 016	3042 468	50 708	60 980	9916 647	594998 795	198 759	11925 558
0 864	2536 694	43 124	50 843	8433 484	496087 328	169 032	9943 075
0 669	2109 388	33 399	42 278	6531 388	412321 341	130 923	8268 169
1 078	3227 224	53 787	64 683	10518 842	631130 522	210 829	12649 766
0 940	2731 084	46 884	54 739	9168 771	534103 147	183 770	10705 026
0 839	2461 486	41 845	49 336	8183 447	481379 255	164 021	9648 782
0 967	2838 776	48 259	56 898	9437 786	555163 900	189 261	11127 147
1 043	2927 734	52 033	58 480	10175 791	570605 116	203 953	11436 611
0 874	2444 227	43 589	48 990	8524 406	478004 085	170 855	9580 611
0 974	2886 107	48 590	57 854	9502 389	564498 359	190 456	11314 738
1 098	3102 265	54 805	62 177	10727 897	606673 434	214 819	12159 552
0 890	2489 850	44 402	49 904	8683 519	486926 309	174 044	9759 462
0 684	2111 121	34 130	42 313	6674 574	412890 265	133 778	8274 916
0 988	2872 824	49 317	57 580	9644 658	562822 388	193 307	11260 601
0 903	2598 594	45 042	52 083	8828 537	508284 852	176 549	10181 546
0 667	2100 799	33 263	42 106	6504 994	410841 735	130 380	8234 499
0 828	2400 039	40 801	48 104	7979 161	469364 398	159 926	9407 478
0 989	2741 228	49 342	54 942	9649 565	536086 960	193 406	10744 788
0 710	2024 735	36 445	40 582	7127 392	395966 242	142 854	7936 349
0 835	2451 631	41 678	49 138	8150 685	479452 062	163 364	9609 655
1 018	2854 051	52 800	57 204	10325 795	558151 078	206 960	11187 019
0 818	2205 362	40 799	44 202	7978 874	432290 472	159 921	8644 333
0 914	2736 626	45 610	54 850	8919 792	535186 943	178 779	10726 749
1 075	3061 632	53 614	61 404	10494 910	598917 726	210 149	12008 514
0 828	2295 680	41 322	46 012	8081 162	448953 442	161 971	8996 371
0 698	2175 694	34 811	43 607	6807 816	425488 525	136 449	8526 064
1 011	2948 775	50 621	59 102	9899 600	576675 699	198 428	11558 308
0 949	2605 339	47 330	52 219	9256 131	509511 811	185 521	10212 142
0 858	2595 586	42 827	52 023	8375 472	507604 391	167 870	10173 962
0 854	2421 966	42 653	48 343	8333 277	473694 906	167 024	9454 178
1 055	2771 298	52 655	55 345	10297 381	541967 413	206 390	10862 650
0 858	2177 652	42 827	43 647	8375 472	425871 480	167 870	8535 760
0 976	2704 099	48 674	54 198	9518 864	528825 752	190 787	10599 252
1 078	2806 325	53 788	56 247	10519 004	548817 620	210 832	10999 949
0 847	2224 239	42 261	44 580	8264 662	434982 225	165 649	8718 146
0 681	1984 545	34 068	39 776	6662 461	388104 552	133 516	7778 777
1 043	2853 214	52 044	56 385	10178 048	550164 746	203 999	11026 949
0 948	2553.930	47 308	50.347	9251 769	491244 353	185 433	9846 038
0 771	2157 454	38 475	43 242	7524 265	421921 421	150 809	8456 569
0 887	2577 093	44 240	51 653	8651 791	503987 841	173 408	10101 426
1 066	2798 138	53 165	56 083	10397 114	547216 542	208 380	10967 858
0 867	2290 123	43 269	44 097	8461 896	433265 880	169 602	8623 827
0 627	2711 042	30 799	34 294	6023 143	334619 040	120 722	6706 768

Figure 54. Cardiac Index and Blood flow calculation output file

Clicking the SYS/DIA/RR button will open a window shown in Figure 55.

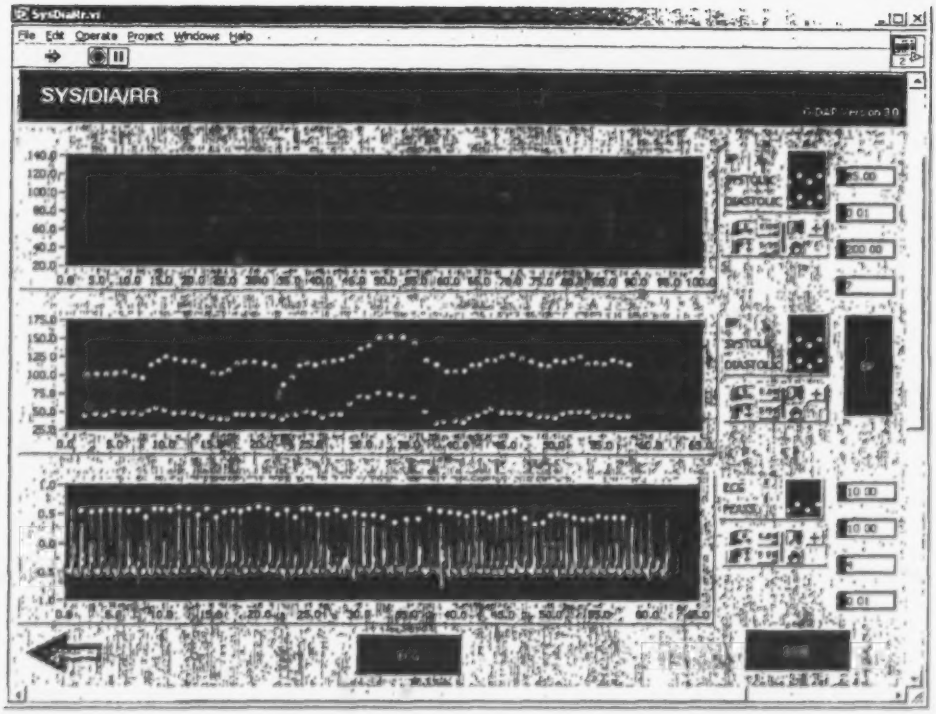


Figure 55. Systolic/Diastolic and R-R interval calculation

For more information please refer to section 8.5.1 for details on this window. It should be noted that a SAVE button is provided for saving ECG and BP signals and the computed peaks into a file. User will define the filename and extension of the data file in the window shown in Figure 56.

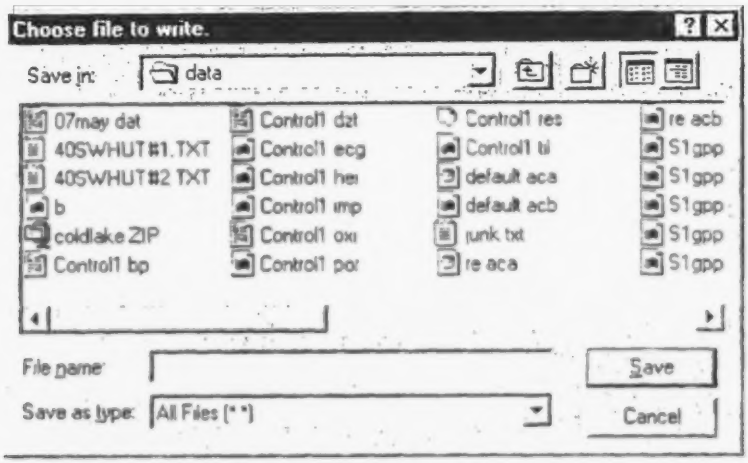


Figure 56. File saving window

Clicking on the PLETHYSMO button will open the window shown in Figure 57. Press the PLOT button to plot the plethysmograph and the blood pressure signals. Figure 58 illustrates the tool for zooming into and out of the region of interest of the plethysmograph and the corresponding BP signals.

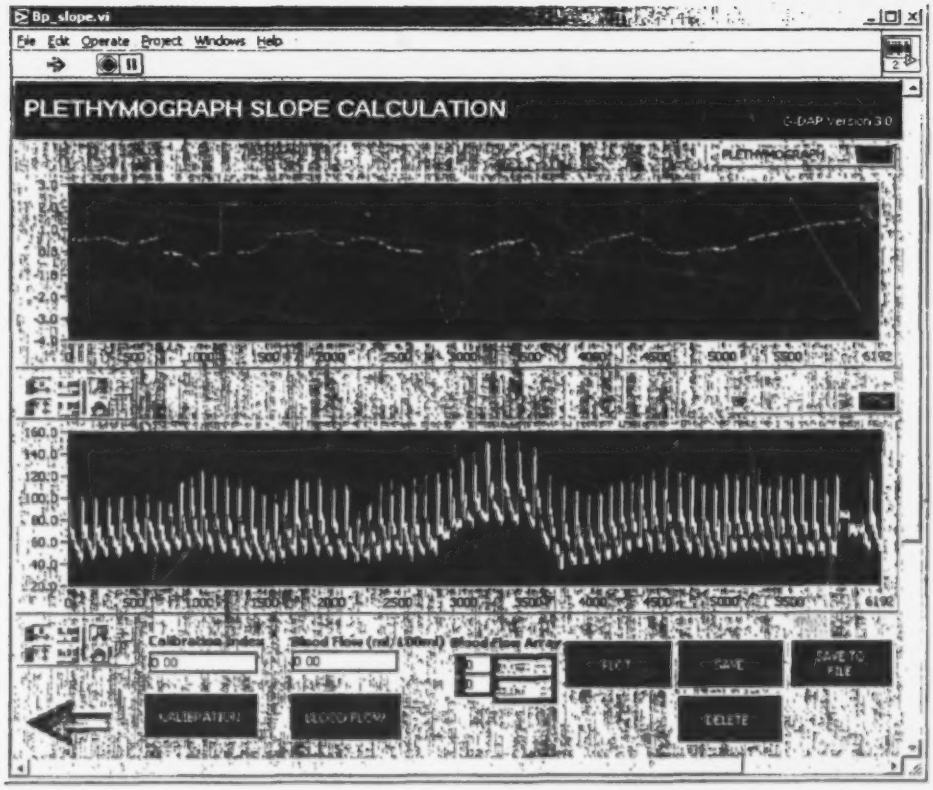


Figure 57. PLETHYSMOGRAPH slope calculation

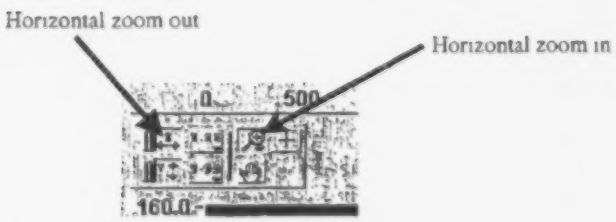


Figure 58. Labview zoom utility

Use the horizontal zoom in Figure 58 to Figure 57 so that the waveform graph only shows the calibration signal portion of the plethysmograph. When the window encompasses the region of calibration signal as shown in Figure 59, press the CALIBRATION button to determine the average calibration value. The average calibration value is shown in the indicator labeled Calibration Index. Note

the corresponding portion of BP signal is shown when plethysmograph signal is zoomed in.

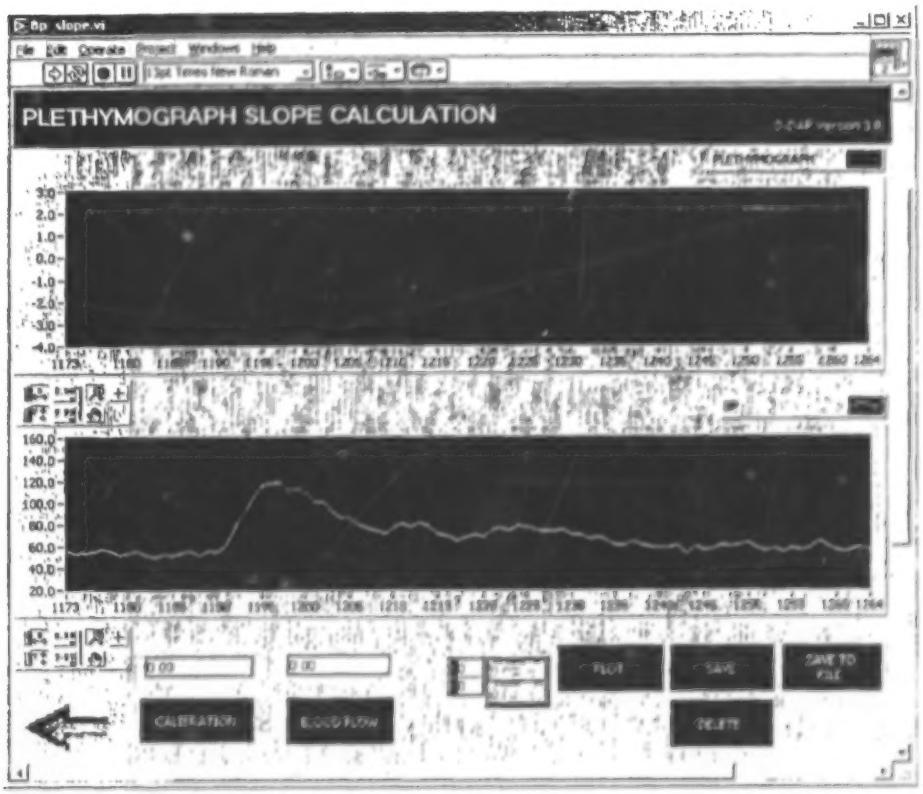


Figure 59. PLETHYSMOGRAPH slope calculation

Use the horizontal zoom out function as shown in Figure 58 to reveal the entire plethysmograph and BP signals. Zoom into the region of interest in the plethysmograph signal before pressing on the BLOOD FLOW button. The blood flow is computed using the calibration index and shown in the indicator labeled Blood Flow. The SAVE button saves the current set of blood flow results, calibration index, start/stop time and the slope of the BP signal into the BF Array. The DELETE button deletes the last set of blood flow results of the BF Array. Click on the SAVE TO FILE button to save the BF Array into a data file. An example data file is shown in Figure 60.

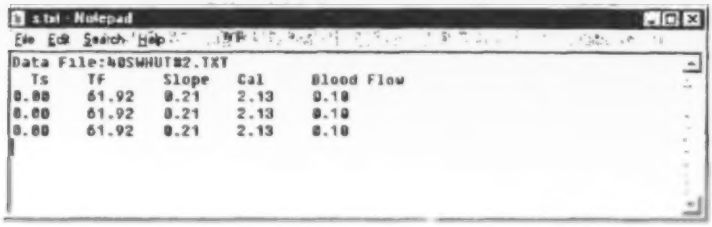

s.txt - Notepad
File Edit Search Help
Data File:ABSWHUT#2.TXT
Ts TF Slope Cal Blood Flow
0.00 61.92 0.21 2.13 0.10
0.00 61.92 0.21 2.13 0.10
0.00 61.92 0.21 2.13 0.10

Figure 60. ASCII data file output

13 OPACITY TOOLBOX

To access the OPACITY toolbox, click on the OPACITY button on the Task Manager window. The OPACITY toolbox has been implemented in G-DAP Version 3. This toolbox allows users to process and analyze opacity signals.

The first window in this toolbox is the DATA LOADING window as shown in Figure 61. Loaded data are listed in the listbox at the right of the window. A maximum of 5 signals can be plotted on the graph. For plotting multiple signals, hold on to the shift key while selecting the data to be plotted.

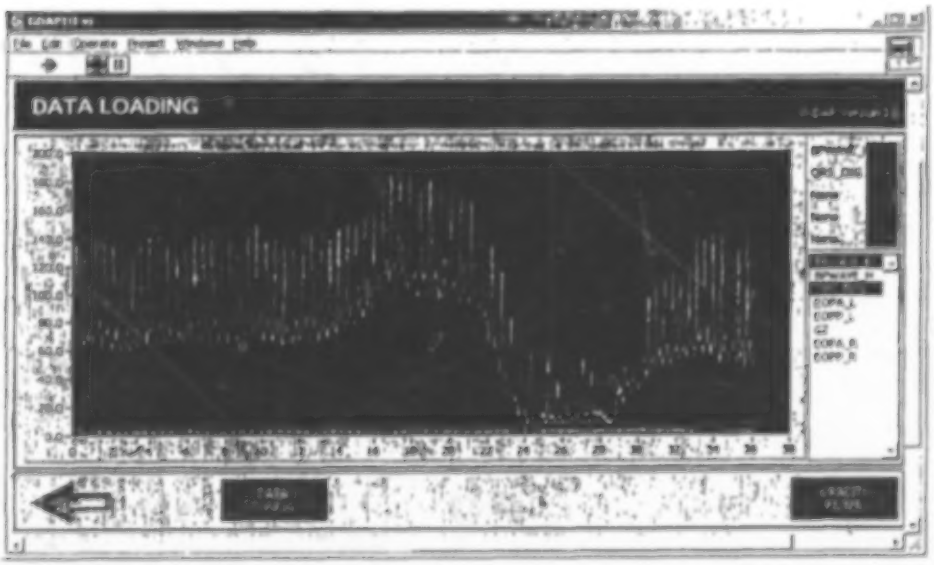


Figure 61. Signal display window

Often a signal of smaller amplitude (QRS_EKG) is plotted with a signal of larger amplitude (BPWAVE_E), and the auto scaling will increase the range of the y-axis to accommodate BPWAVE_E. By doing so, QRS_EKG will be too small to be observed on the graph. The DATA CONFIG button at the bottom of the window opens the CHANNELS CONFIGURATION windows as shown in Figure 62. Users are able to change the gain (e.g. 50) and offset of QRS_EKG so that its amplitude is comparable to that of BPWAVE_E. When users return to the DATA LOADING window, QRS_EKG and BPWAVE_E can be observed on the graph with the same y-axis range as shown in Figure 63.

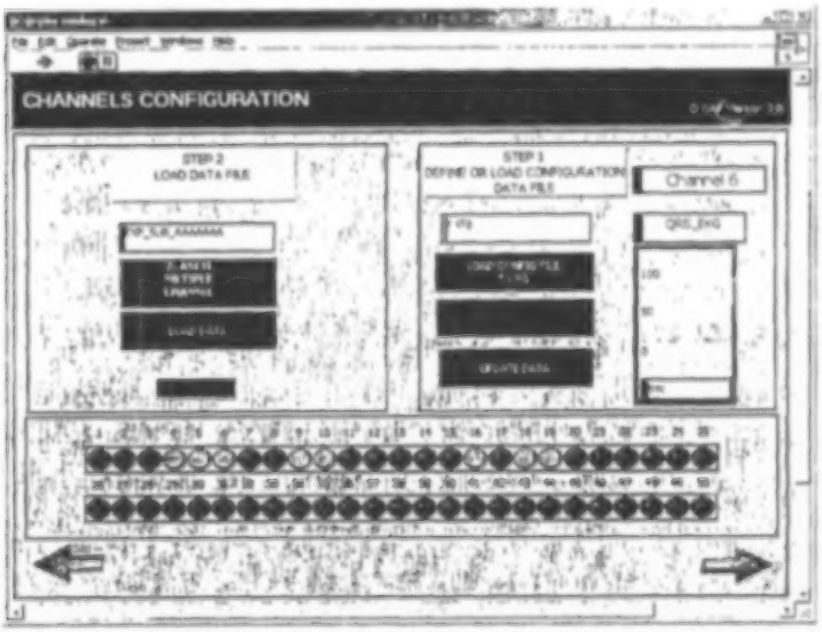


Figure 62. Channel configuration window

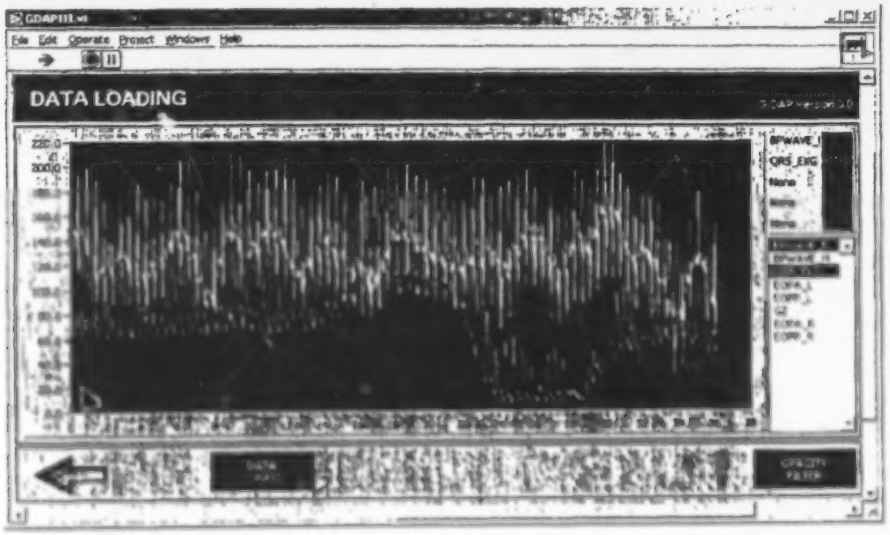


Figure 63. Loaded data display window

The OPACITY FILTER button opens the OPACITY FILTER window as shown in Figure 64. In this window, left opacity, right opacity, and G_z can be plotted. The two check boxes, OPA(L) w Filter and OPA(R) w Filter, located on the right of the window apply filters to the raw opacity signals and plot them on the graph. Filters such as lowpass, highpass, bandpass, and bandstop filters are provided to allow users to suppress noise in the signals.

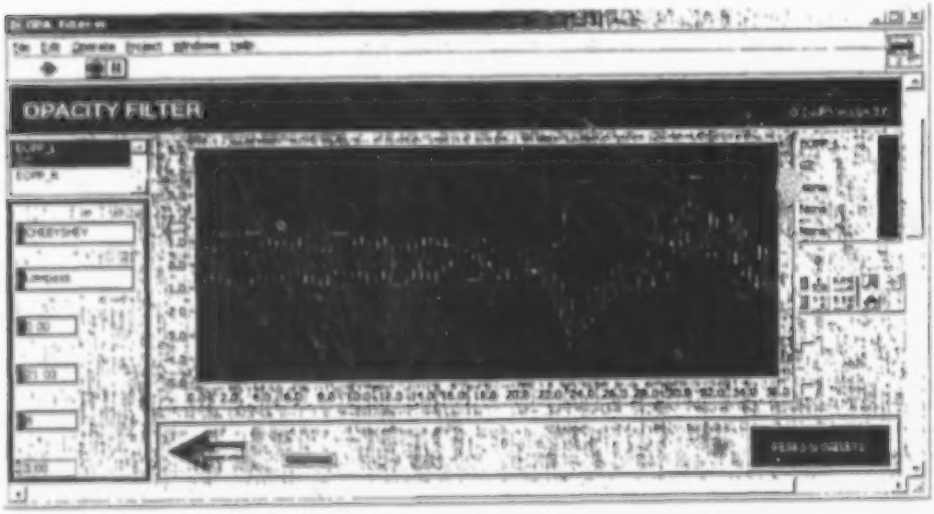


Figure 64. Opacity filter utility window

Figure 65 plots the left opacity signal, G_z and filtered left opacity signal. The filter parameters are defined in the box on the left side of the window. Note that the default check box on the bottom of the screen is deselected. User can then change the parameters for calculating the peaks and valleys of the opacity signals by clicking on the PEAKS & VALLEYS PARAMETERS button.

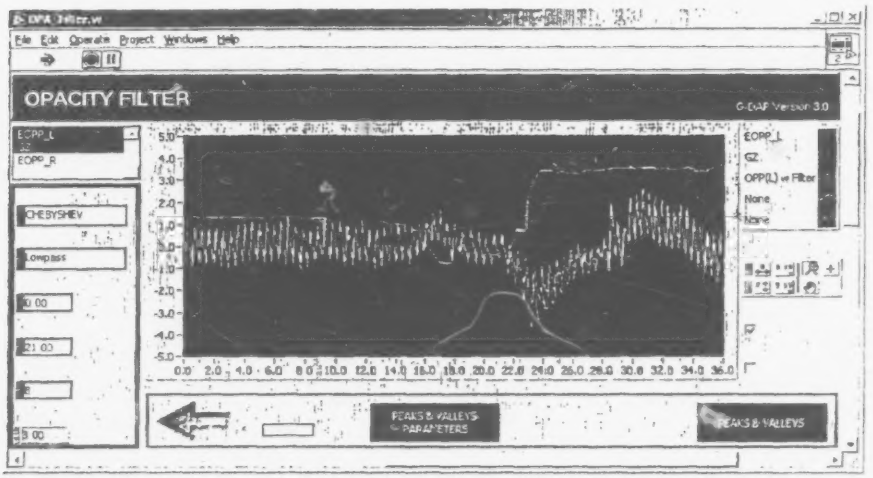


Figure 65. Opacity filter setting parameters window

Figure 66 shows the window with the parameters that can be defined by the user. The default values are 0.12 for Init_PWD and 0.5 for Init_earOpaRS.

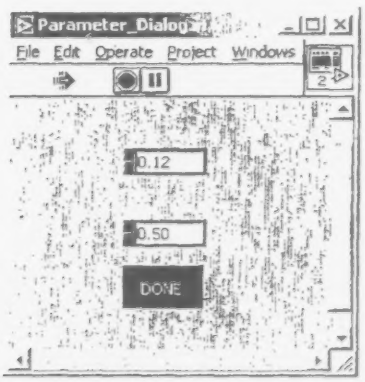


Figure 66. User's defined calculation parameters

Once the PEAKS & VALLEYS PARAMETERS are defined, user can proceed to compute the peaks and valleys of the opacity signal by clicking the PEAKS & VALLEYS button as shown in Figure 67. A moving average control on the left side of the screen defines the number of data points to average the amplitude between the peaks and valleys of the opacity signal. This moving average acts as a lowpass filter which smoothes the irregularities in the amplitude.

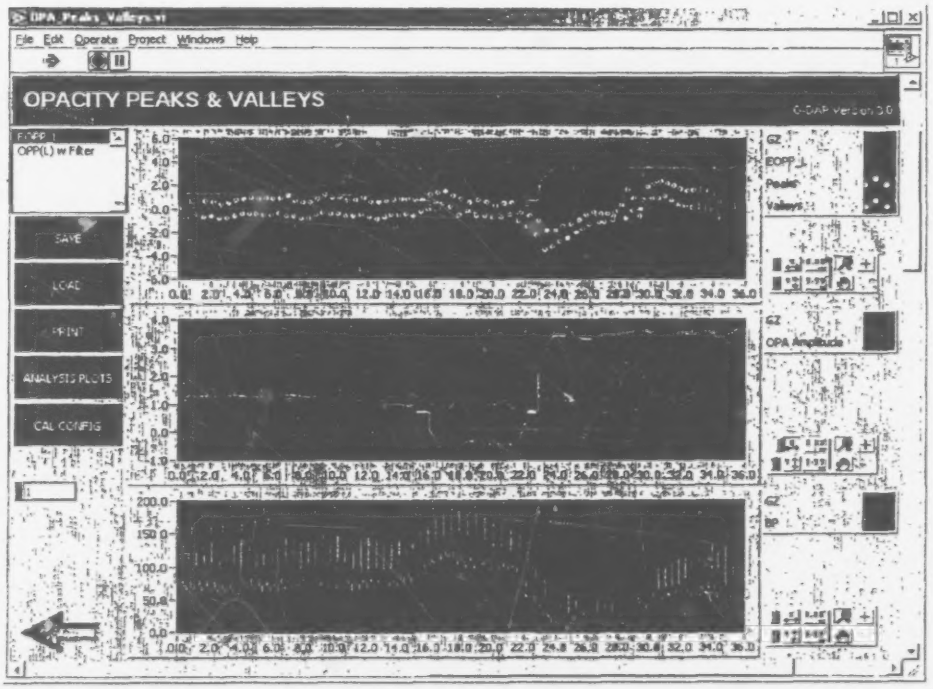


Figure 67. Calculated peaks and valleys for blood pressure and opacity signals

The SAVE and LOAD button on the left side of the window saves and loads the opacity signal, Gz, and peaks and valleys time and amplitude to a text file defined by the user. The PRINT button will print the screen of the vi.

The ANALYSIS PLOTS button opens the screen shown in Figure 68. The figure shows a point 3D plot with HEAD_BP (diastolic) as the X-axis, G_z as the Y-axis, and EOPP_R (max) as the Z-axis. The Systolic and Diastolic check boxes on the right side of the window define if the systolic or diastolic points will be used for

the BP when plotting. The OPA (max) and OPA (min) check boxes determine if peaks or valleys are used in the plot of the opacity signal.

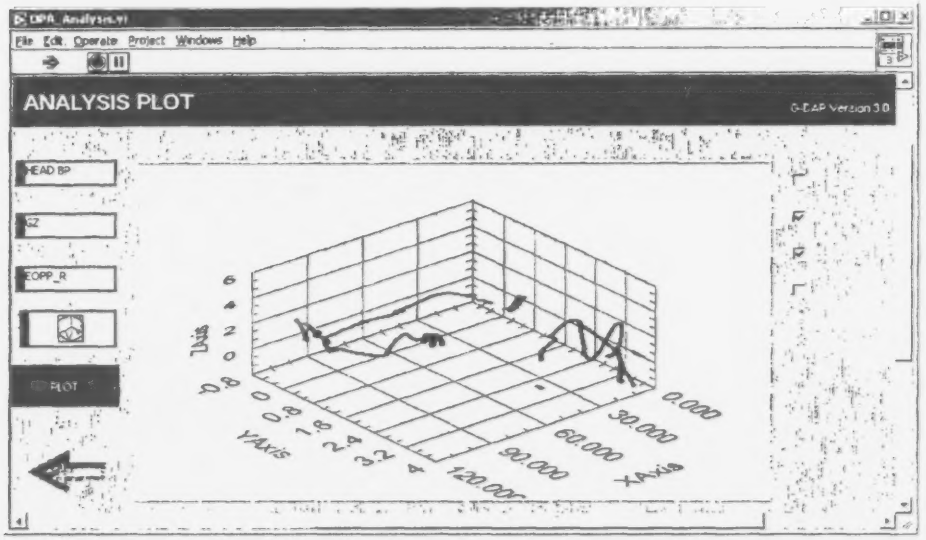


Figure 68. 3D analysis plot utility

A 3D surface plot is shown in Figure 69. The X-, Y-, and Z-axes form the 3 data sets. X-axis corresponds to data set 0, Y-axis to data set 1, and Z-axis to data set 2.

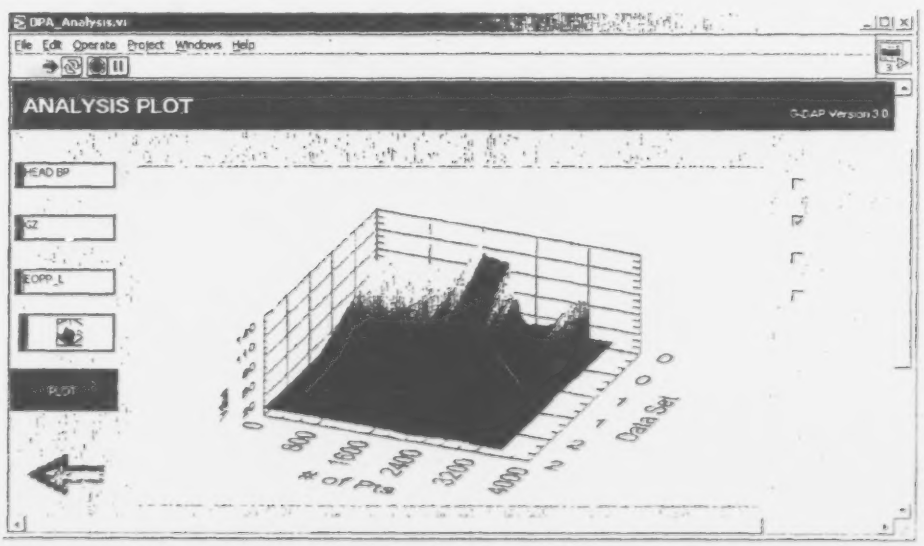


Figure 69. 3D analysis surface plot

Figure 70 shows the 2D XY plot of diastolic head BP and G_z

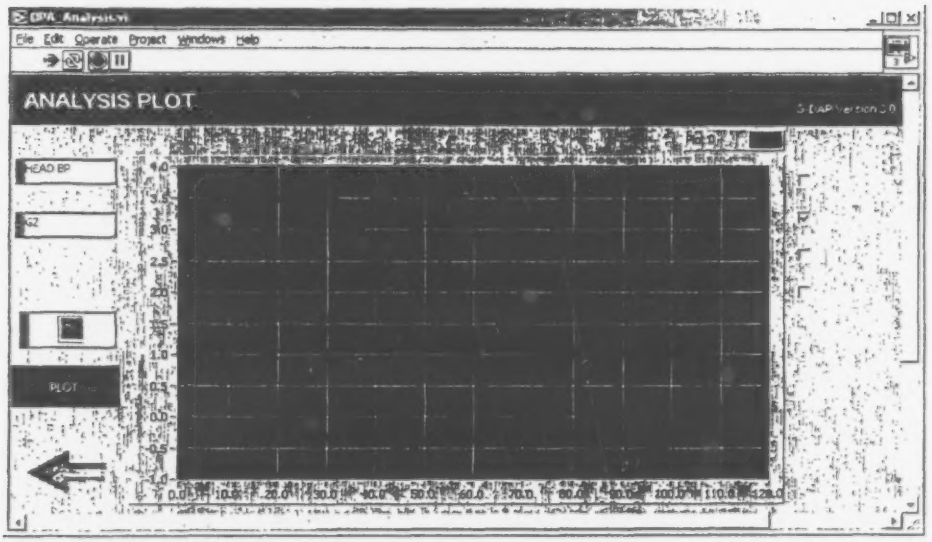


Figure 70. 2D analysis plot

The CAL CONFIG button opens the ACCELERATION PROFILES window. Please refer to section 8.5.2 for details on acceleration profiles. The following is the definition of the opacity signals:

R_OPP: Right opacity pulse that is chosen in the OPACITY PEAKS & VALLEYS window.

R_OPA: Right opacity amplitude given in the loaded data file.

L_OPP: Left opacity pulse that is chosen in the OPACITY PEAKS & VALLEYS window.

L-OPA: Left opacity amplitude given in the loaded data file.

CAL_OPA: Opacity amplitude that was computed in the OPACITY PEAKS & VALLEYS window.

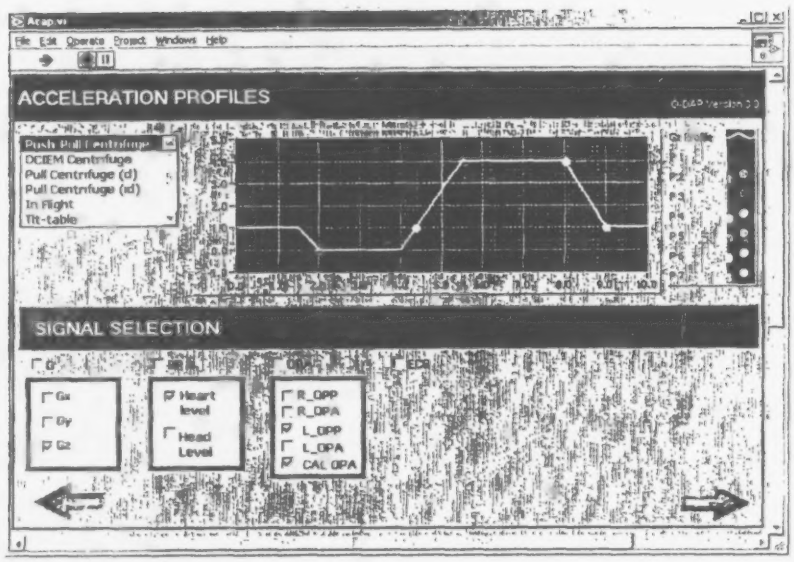


Figure 71. Acceleration profile window

Figure 71 shows the G_z reference modification window. Please refer to section 8.5.3 for details on this window.

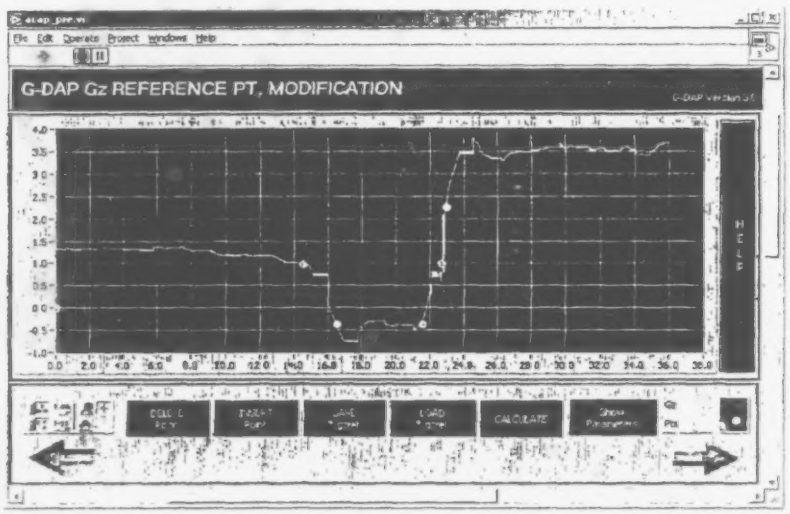


Figure 72. Gz reference points modification window

Please refer to section 11 for details on Figure 73 and Figure 74.

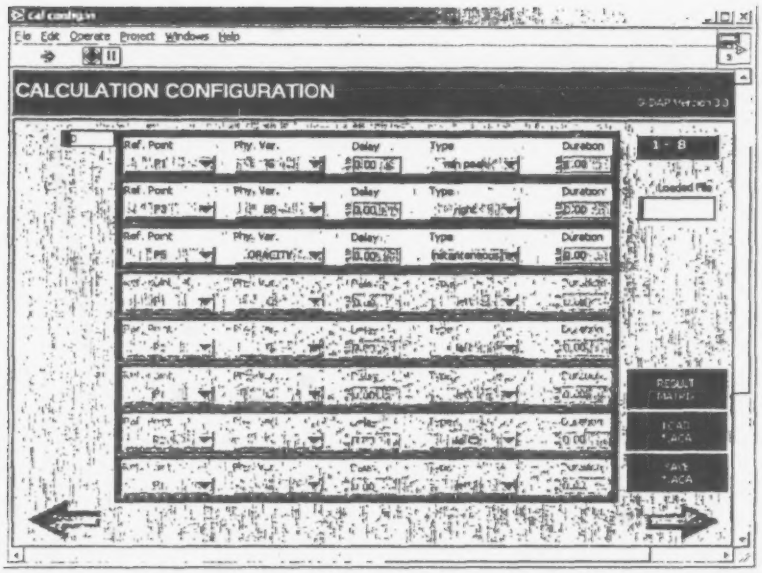


Figure 73. Calculation configuration window

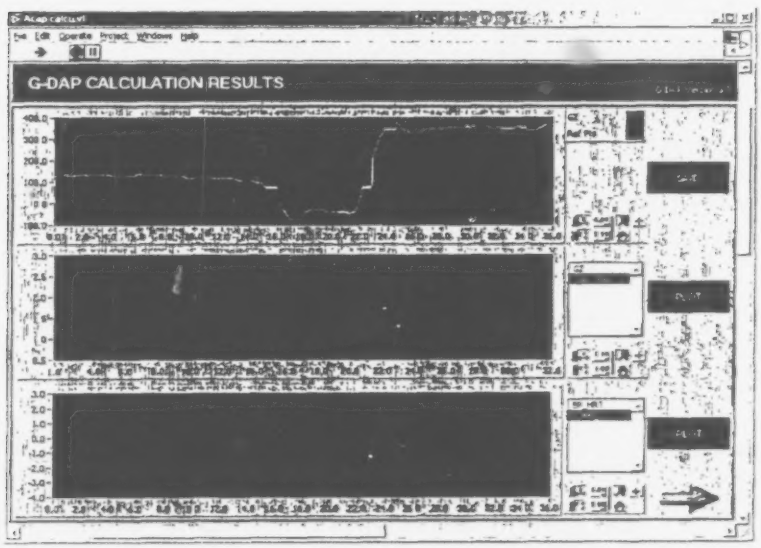


Figure 74. Calculation results

14 FLOWCHART OF OPACITY ALGORITHM AND EXAMPLES

Flowchart of G-DAP-3 algorithm for calculating amplitudes of ear opacity pulses is presented in Figure 75. Figure 76 is an example that illustrates results generated by this algorithm. Figure 76 shows peaks and valleys of an ear pulse signal during a rest period, as they are identified by the algorithm. The other example is in Figure 77 that shows peaks and valleys of an ear pulse signal during a G-run.

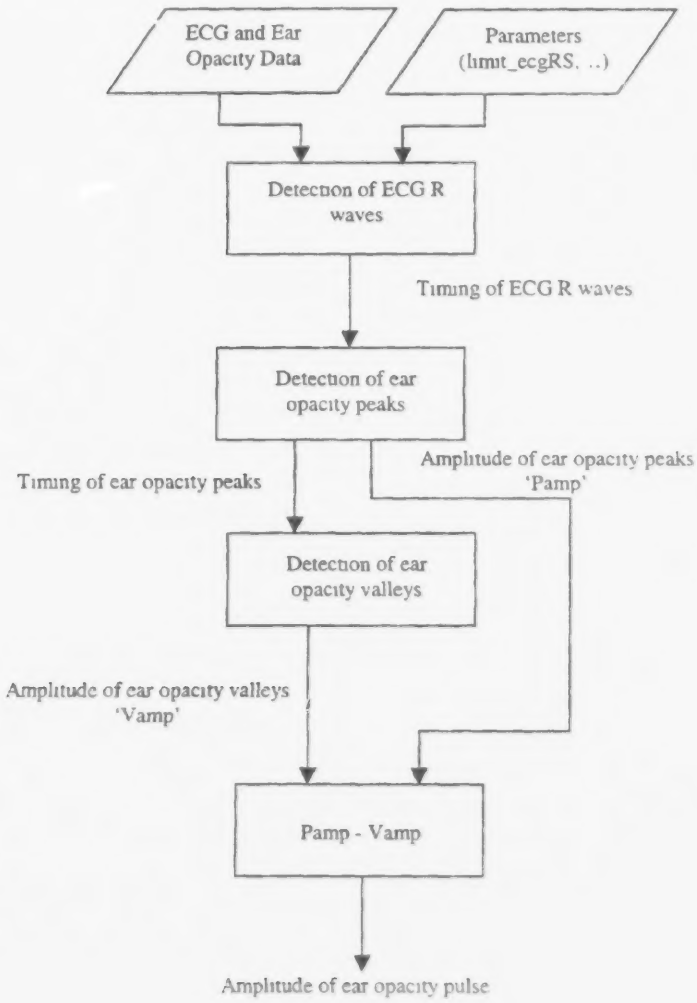

ECG and Ear Opacity Data
Parameters (limit_ecgRS, ..)
Detection of ECG R waves
Timing of ECG R waves
Detection of ear opacity peaks
Timing of ear opacity peaks
Amplitude of ear opacity peaks 'Pamp'
Detection of ear opacity valleys
Amplitude of ear opacity valleys 'Vamp'
Pamp - Vamp
Amplitude of ear opacity pulse

Figure 75. Flowchart of G-DAP-3 Algorithm for Calculating Amplitude of Ear Opacity Pulse

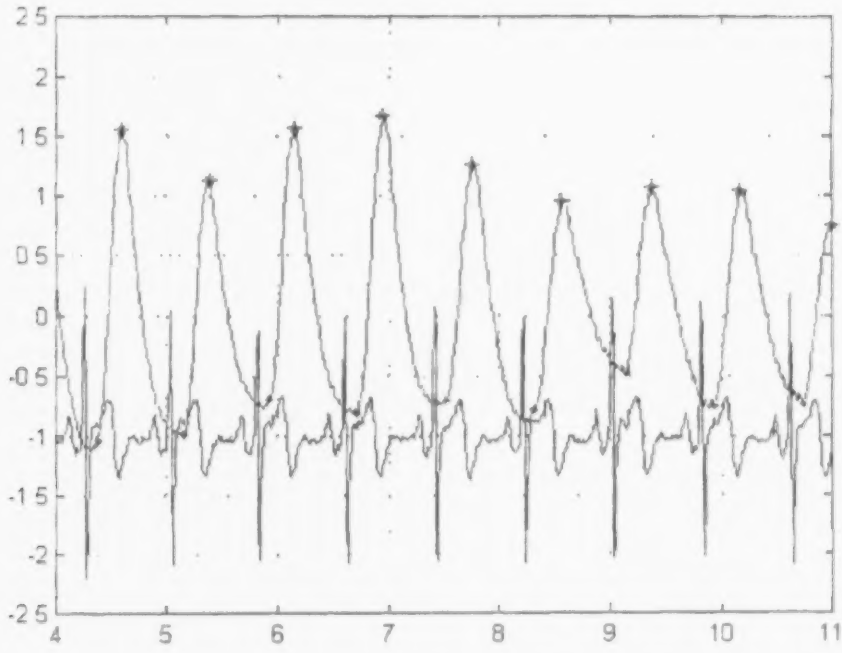


Figure 76. Identification of peaks and valleys of ear pulse signal during resting period

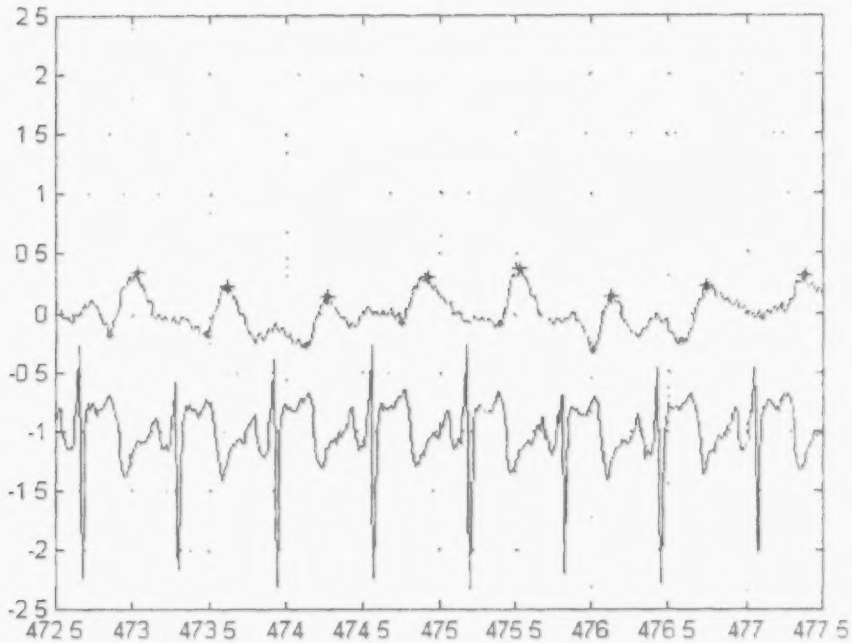


Figure 77. Identification of peaks and valleys of ear pulse signal during G run period

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14 ABSTRACT

(U) This final report summarizes the development and implementation of advancements and modifications for G-DAP software package. G-DAP (The Acceleration /Gz/ Data Analysis Package) is a Labview-based package for custom-designed analysis of physiological data pertinent to acceleration physiology research conducted at DRDC-TORONTO. G-DAP automates review, playback, signal processing, and analysis of data acquired in human centrifuge, tilt-table or flight experiments. Furthermore, G-DAP automatically calculates predefined and/or custom-defined physiological indices used in acceleration physiology research, such as blood flow analysis and calculation of related indices (e.g., cardiac index), and ear-opacity signals identification and analysis (based on an adaptive peak detection algorithm). In this project, new functions are added that enable more sophisticated and comprehensive analysis, as well as handling new types of advanced acceleration research and experimental protocols performed using both Tilt-Table setup and human centrifuge.

(U) Le présent rapport final résume le développement du progiciel G-DAP ainsi que les améliorations et les modifications apportées à ce dernier. G-DAP (de l'anglais Acceleration /Gz/ Data Analysis Package) est un progiciel fondé Labview servant à l'analyse personnalisée des données physiologiques relatives à la recherche en physiologie de l'accélération menée à RDDC Toronto. G-DAP automatise l'examen, la relecture, le traitement des signaux et l'analyse des données acquises lors d'expériences en centrifugeuse humaine, en table basculante ou en vol. De plus, G-DAP calcule automatiquement les indices physiologiques prédéfinis et/ou personnalisés utilisés pour la recherche en physiologie de l'accélération, comme l'analyse du débit sanguin et le calcul des indices connexes (p. ex. l'indice cardiaque), ainsi que l'identification et l'analyse des signaux d'opacité auditive (d'après un algorithme adaptatif de détection des sommets). Dans ce projet, de nouvelles fonctions sont ajoutées afin de permettre une analyse plus poussée et plus détaillée ainsi que de traiter de nouveaux types de protocoles poussés de recherche et d'expérience en accélération menés en présence d'une table pivotante et d'une centrifugeuse humaine.

15 KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) data analysis software; Labviews; acceleration physiology; research; human centrifuge; tilt-table; adaptive peak detection algorithm; simulated air combat maneuver

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